KENAI NATIONAL WILDLIFE REFUGE

OIL AND GAS ASSESSMENT

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

KENAI NATIONAL WILDLIFE REFUGE
OIL AND GAS ASSESSMENT

by

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Christopher Gibson
Aden Seidlitz
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EXECUTIVE SUMMARY

The area of the Kenai National Wildlife Refuge (KNWR) has attracted significant oil exploration activity since the 1950s. This interest has continued until the present, with the last well being completed in 1985. Contacts with the oil industry indicate that this interest continues. This study of the hydrocarbon resource potential of KNWR indicates that the refuge may be divided into two areas; one of high potential and one of low potential.

The area of high potential is that part of the refuge lying west of a line between the eastern side of Chickaloon Bay and the northern end of Kachemak Bay. The remainder of the refuge has a low potential for hydrocarbon resource occurrences.

KNWR may also be divided into two areas of different oil and gas development potential. These areas correspond exactly to the areas of hydrocarbon resource potential and have the same relative rankings.

Interest in oil and gas exploration in KNWR ranks as moderate due to the current low oil prices, and could remain at that level until the mid-1990s, at which time the trend of increasing oil prices may change the interest in KNWR to high. Moderate interest means that there should be requests for permits to do surficial geologic work every year, and at least one request for a permit to do helicopter transported seismic exploration or drilling every three to five years. Any upturn in oil prices will cause a corresponding increase in interest in the area.

ILLUSTRATIONS

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INTRODUCTION

The purpose of this report is to provide an oil and gas resource assessment of the Kenai National Wildlife Refuge (KNWR) to be included as part of the "comprehensive conservation plan" for the Refuge as mandated by Sections 1008 and 304(g) of the Alaska National Interest Lands Conservation Act (ANILCA).

The U.S. Bureau of Land Management (BLM) is conducting the resource assessment at the request of the U.S. Fish and Wildlife Service (FWS) as set forth in a Memorandum of Understanding between the FWS and BLM (Appendix A).

The purpose of this report is:

1. To identify areas of differnt hydrocarbon resource potential.

2. To illustrate and discuss a hypothetical development scenario within KNWR.

3. To present an economic assessment of oil and gas production from the KNWR.

Description of Geology

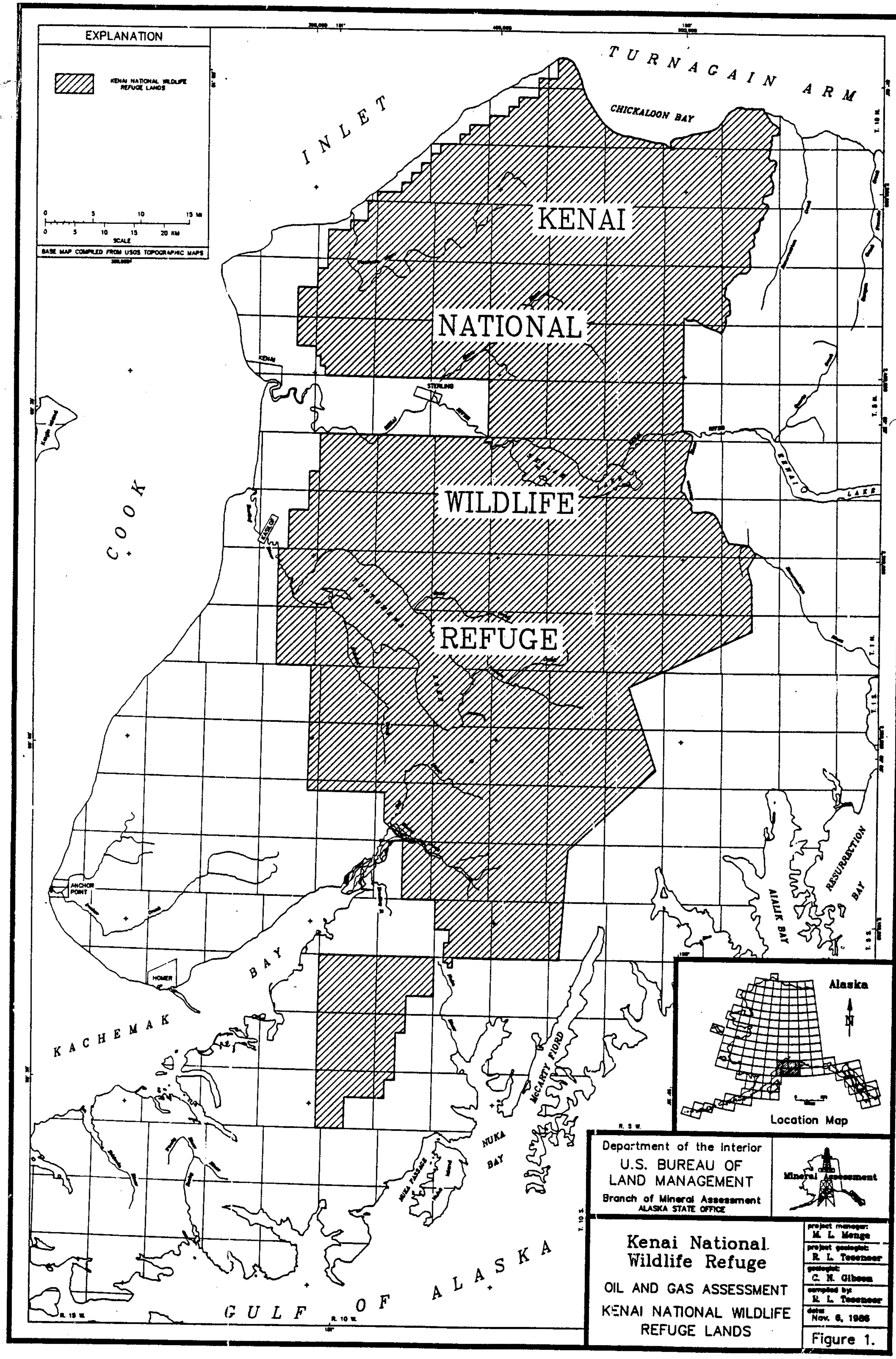
Previous Work

Geologic investigations of southeastern Alaska by the U.S. Geological Survey (USGS) began prior to 1900, with an increase in the level of work in the 1930s. There was another increase in the number of investigations performed in the 1950s, at which time the oil industry became increasingly interested in the Cook Inlet Basin. This industry interest led to the discovery of oil at the Swanson River Field in July 1957. Many of the papers discussing the geology of the Cook Inlet Basin and KNWR are listed in the bibliography (page 51).

Physiography

KNWR is located on the Kenai Peninsula in southcentral Alaska (figure 1). The Refuge encompasses 1.97 million acres, of which about 660,000 acres lie within the Kenai Range of the Kenai-Chugach Mountains section of the Pacific Border Ranges physiographic province. The remaining two-thirds of the Refuge lies within the Kenai lowland area of the Cook Inlet-Susitna Lowland section of the Coastal Trough province (Wahrhaftig, 1965).

The Kenai Range within KNWR is comprised of steep, rugged mountains and narrow glacial valleys. The topography is characterized by glacial features, with horns, aretes, cirques, etc., being common. Glaciers are common, and the highest part of the mountains are buried beneath the Harding Icefield.


EXPLANATION
KENAI NATIONAL WILDLIFE REFUGE LANDS
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
COOK INLET
KENAI
STERLING
KENAI NATIONAL WILDLIFE REFUGE
ANCHOR POINT
HOMER
KACHEMAK BAY
NUKA BAY
McCARTY FIORD
AIALIK BAY
RESURRECTION BAY
GULF OF ALASKA
Alaska
Location Map
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ALASKA STATE OFFICE
Mineral Assessment
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
KENAI NATIONAL WILDLIFE REFUGE LANDS
project manager: M. L. Menge
project geologist: R. L. Tessneer
geologist: C. N. Gibson
compiled by: R. L. Tessneer
date: Nov. 6, 1986
Figure 1.

Elevations of the Kenai Range within the Refuge range from 3,000 to 6,600 feet (900 to 1,800 m). Most streams in the Kenai Range are short and swift, heading in glaciers. There are several lakes filling valleys in the northern Kenai Range, but no major ones within the Refuge (Wahrhaftig, 1965).

The Kenai lowland is a glaciated lowland containing areas of ground moraine and stagnant ice topography. Most of the lowland is less than 500 feet (150 m) in elevation, although some rolling upland areas approach 3,000 feet (900 m) near the Kenai Range. There are two large lakes in the Kenai lowland (Tustumena and Skilak) whose basins were carved by glacial ice. Numerous small lakes and ponds occur in areas of stagnant ice topography and on ground moraines, most of these are north of the Kenai River. The major drainage crossing the Kenai lowland is the Kenai River.

Rock Units (Lithology and Stratigraphy)

The surficial geology of KNWR is limited to primarily three rock types: (1) Valdez Group, (2) McHugh Complex, and (3) surficial material (plate 1).

The stratigraphy of KNWR can be divided into two parts. Figure 2 is a columnar section for the area east of the Knik Fault, and figure 3 is a stratigraphic section for the area west of the Knik Fault.

Eastern KNWR

The Late Cretaceous Valdez Group is composed of complexly deformed sandstones, graywackes, slates, and argillites that have been metamorphosed to the greenschist facies. Portions of the Valdez Group are interpreted to be turbidite sequences (Clark, 1972; Jones and Clark, 1973). The Valdez Group is structurally overlain by the older McHugh Complex.

The Jurassic-Cretaceous McHugh Complex consists of a chaotic mixture of volcanic and sedimentary rocks that have undergone prehnite-pumpellyite facies metamorphism. The major rock types are siltstone, conglomeratic sandstone, graywacke, and arkosic sandstone. The volcanic rock includes pillow basalts with associated cherts. Ultramafic rocks and marbles occur locally.

Western KNWR

The stratigraphic section of western KNWR consists of two major rock groups which are separated by a major angular unconformity (figure 3) (Boss et al, 1976). The older group is Middle Jurassic to Upper Cretaceous in age, and the younger group is Tertiary in age. This relationship is shown in plate 1 and figure 4.

Lower Triassic and Older

Lower Triassic and older volcanic and metamorphic rocks similar to those exposed across Cook Inlet are presumed to underlie KNWR.

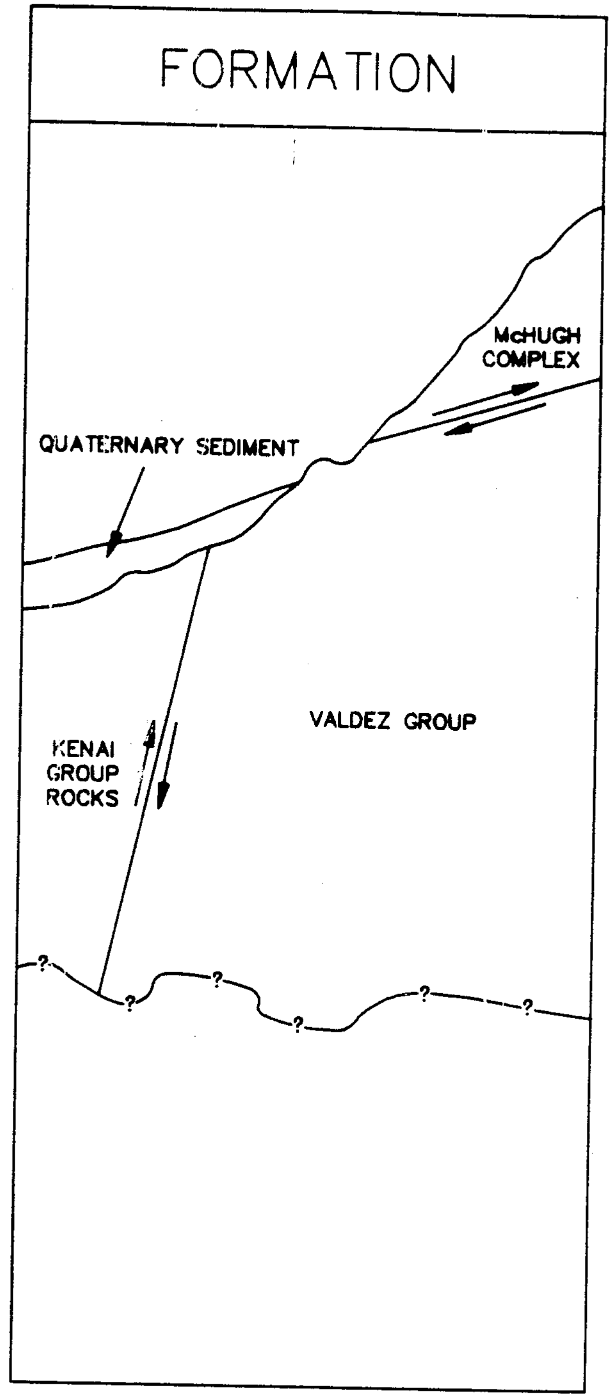


Figure 2. Columnar section of the eastern one-third of the Kenai National Wildlife Refuge. (Vertical scale not uniform.)

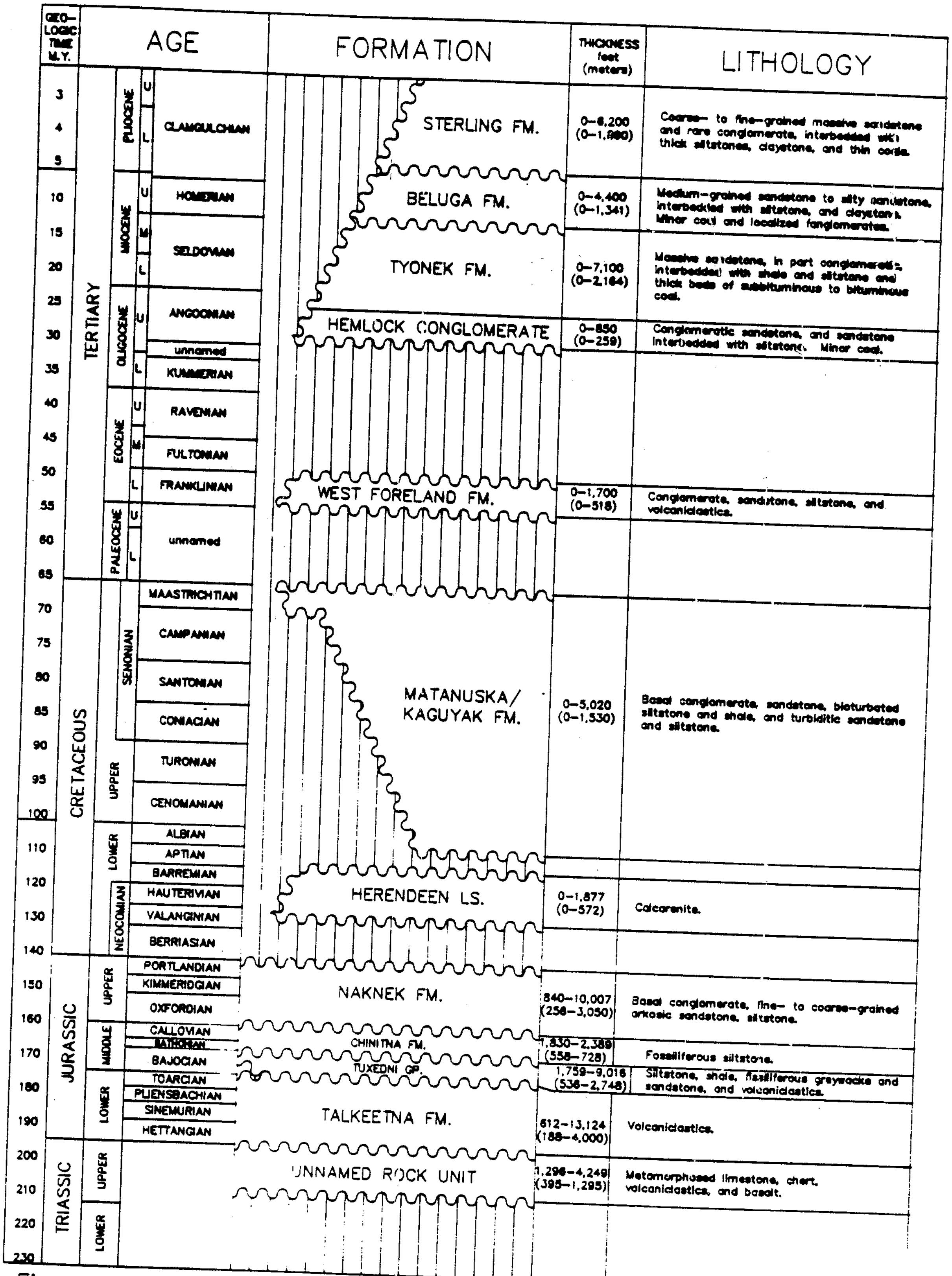
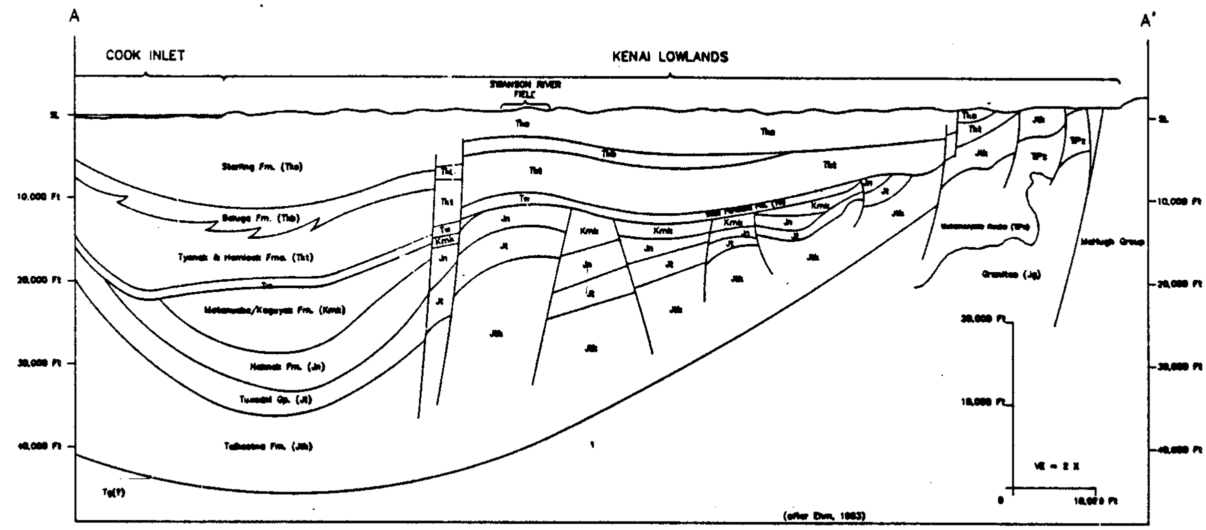
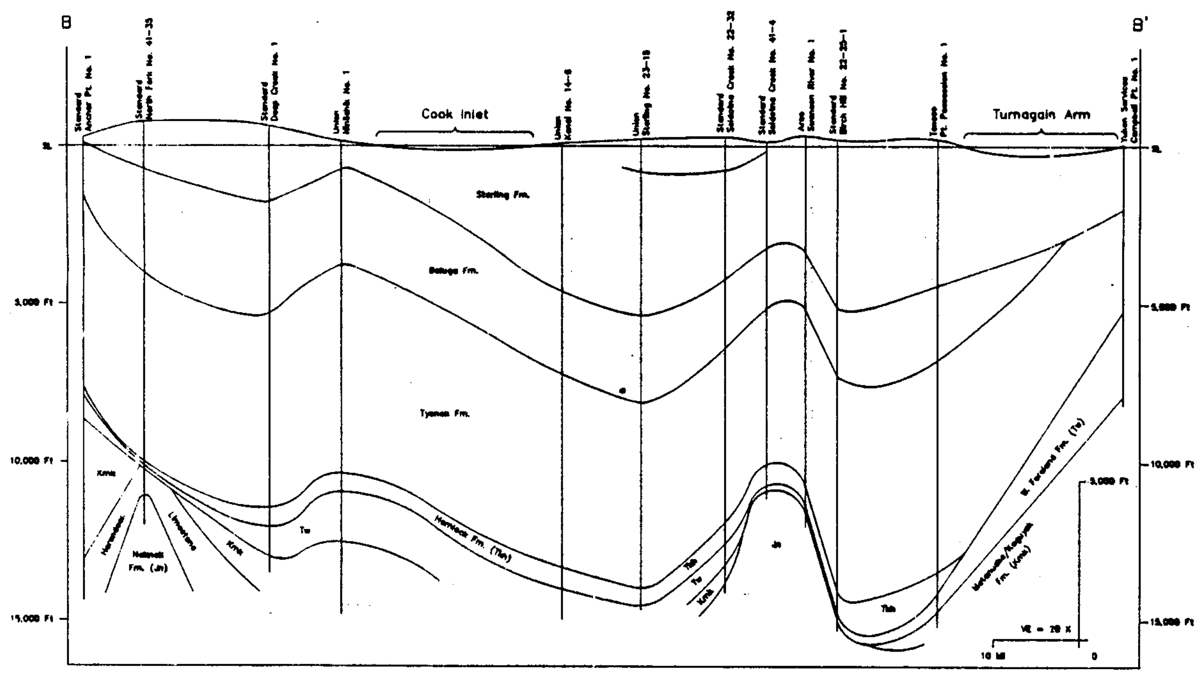
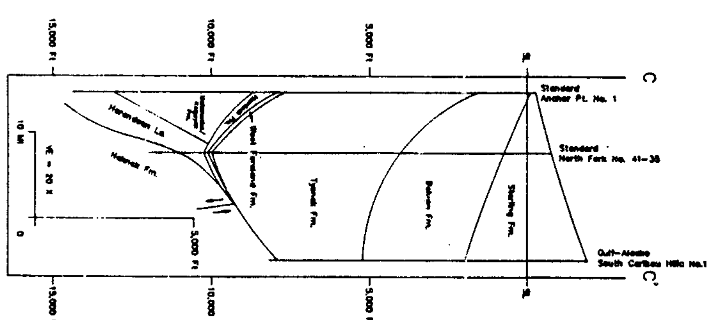


Figure 3. Stratigraphic section for the western two–thirds of the Kenai National Wildlife Refuge (pre–Triassic rocks and recent sediments not included). (Modified from Magoon et al, 1976a.)







LINES OF CROSS SECTIONS ON PLATE 1.

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Kenai National Wildlife Refuge

OIL AND GAS ASSESSMENT

CROSS SECTIONS
A–A', B–B', AND C–C'

project manager: M. L. Menge
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compiled by: R. L. Tessmer
date: Nov. 5, 1986

Figure 4.

Upper Triassic

Overlying the Middle Triassic and older metamorphic rocks is an unnamed rock unit composed of metamorphosed limestone, chert, volcaniclastic rocks, and basalt. These rocks are exposed in the Iniskin-Tuxedni region, across Cook Inlet where they are up to 1,300 feet (400 m) thick, and in the Seldovia area (Detterman and Hartsock, 1966). The presence of this unit on both sides of Cook Inlet suggests that it extends under the inlet and presumably to the north under KNWR; however, no wells have penetrated Triassic rocks.

Lower Jurassic

The Lower Jurassic Talkeetna Formation unconformably overlies the Upper Triassic unnamed unit. The Talkeetna Formation is exposed on both sides of Cook Inlet. In the Iniskin-Tuxedni region, it is more than 9,000 feet (2,740 m) thick and has three distinct members, the Marsh Creek Breccia, massive dark green volcanic breccia and argillite; Portage Creek Member, massive red and pink conglomerates, tuff breccias, and argillites; Horn Mountain Member, tuff and thinly bedded to massive tuffaceous sandstones (Detterman and Hartsock, 1966). Near Port Graham, at the southern end of the Kenai Peninsula, the Talkeetna Formation consists of over 4,500 feet (1,370 m) of massive volcanic conglomerates, tuffs, and sandstones (Boss et al, 1976). The Talkeetna Formation has been penetrated by a few wells on the Kenai Peninsula and is considered to be "economic basement" (Boss et al, 1976).

Middle Jurassic

The Middle Jurassic (Bajocian) Tuxedni Group unconformably overlies the Lower Jurassic Talkeetna Formation. Up to 10,000 feet (3,000 m) of Tuxedni Group rocks are known to exist. Marine sandstone, conglomerate, siltstone, and shale are the major rock types of the Tuxedni Group. A few wells on the Kenai Peninsula have penetrated Tuxedni Group rocks, and some of these have had oil shows in the Tuxedni Group.

The Middle Jurassic (Bathohian to Callovian) Chinitna Formation unconformably overlies the Middle Jurassic Tuxedni Group (Boss et al, 1976). The Chinitna Formation is composed of up to 2,000 feet (600 m) of dark gray fossiliferous marine siltstones (Detterman and Hartsock, 1966).

Upper Jurassic

The Upper Jurassic Naknek Formation unconformably overlies the Upper Jurassic Chinitna Formation. The Naknek Formation extends laterally from the Talkeetna Mountains to the Black Hills near Cold Bay, Alaska (Wilson, Detterman, and Case, 1985). The Naknek Formation ranges from 5,000 feet (1,500 m) thick in the Iniskin-Tuxedni area to as much as 10,000 feet (3,000 m) in more complete exposures in the Alaska Peninsula (Boss et al, 1976). In outcrop, the Naknek is composed of boulder conglomerates and interbedded coarse-grained sandstones, but where it has been penetrated by wells, it is finer grained, with fine-grained sandstones and shales probably predominating (Boss et al, 1976). The Naknek Formation may record the unroofing of the Alaska-Aleutian Range batholith (Magoon et al, 1976a).

Lower Cretaceous

On the Kenai Peninsula, the Lower Cretaceous Herendeen Limestone unconformably overlies the Upper Jurassic Naknek Formation. The Herendeen Limestone apparently has a wide lateral extent, although it is exposed in few locations. The Herendeen Limestone is a calcarenite that contains abundant Inoceramus prisms (locally up to 50 percent). Grantz et al (1966) and Bergquist (1961) have correlated the Herendeen Limestone with the Nelchina Limestone, east of the Matanuska Valley and in the southwestern Wrangell Mountains, while Jones and Detterman (1966) have correlated it with a lithologically similar unit in the Kamishak Hills. The Herendeen Limestone is 13,000 feet (400 m) thick near Anchor Point, but may not be present under KNWR, as it has not been penetrated by any wells on the Kenai Peninsula north of Anchor Point.

Upper Cretaceous

The Upper Cretaceous Matanuska/Kaguyak Formation is angularly unconformable with the underlying Lower Cretaceous Herendeen Limestone (where present) and the Upper Jurassic Naknek Formation. The Matanuska/Kaguyak Formation is up to 4,500 feet (1,370 m) of marine sandstone, bioturbated siltstone and shale, and turbiditic sandstone and siltstone. The Matanuska/Kaguyak Formation is locally absent in KNWR.

The division that separates the Matanuska Formation from the Kaguyak Formation is apparently geographical rather than geological. South of an east-west line drawn from Tuxedni Bay, on the Alaska Peninsula, to the Kenai Peninsula, these rocks are referred to as the Kaguyak Formation, and north of this line they are referred to as the Matanuska Formation (Magoon, personal communication, 1986). The name Kaguyak Formation is assigned to a series of shallow marine conglomerates, sandstones, bioturbated siltstones, turbiditic sandstones, and siltstones in the Kamishak Hills-Cape Douglas area (Fisher and Magoon, 1978; Magoon et al, 1978). A series of turbiditic siltstones, shales, sandstones, and conglomerates in the Matanuska Valley are assigned to the Matanuska Formation (Grantz, 1964). These rocks have been correlated by Wilson, Detterman, and Case (1985), who refer to them as the Matanuska/Kaguyak Formation.

Cross section A-A' (figure 4) shows that the Matanuska/Kaguyak Formation unconformably overlies Upper and Middle Jurassic strata, while cross section C-C' (figure 4) shows that the Matanuska/Kaguyak Formation unconformably overlies the Lower Cretaceous Herendeen Limestone. The northern unconformity (section A-A'), as compared to the southern one (C-C'), indicates extensive Cretaceous erosion in the northern KNWR, or possibly may reflect a structural truncation or non-depositional hiatus in the Early Cretaceous (Boss et al, 1976).

Tertiary

Five formations comprise the Tertiary Kenai Group; from oldest to youngest, they are the West Foreland Formation, the Hemlock Comglomerate, the Tyonek Formation, the Beluga Formation, and the Sterling Formation. The thickness of the Kenai Group ranges from 0 to 17,600 feet (0-5,400 m) within KNWR, as shown in figure 5. The Kenai Group reaches a maximum thickness of 26,000 feet (7,900 m) under Cook Inlet. The Kenai Group unconformably overlies the Matanuska/Kaguyak Formation, and locally unconformably overlies Upper and Middle Jurassic rock units.

Eocene

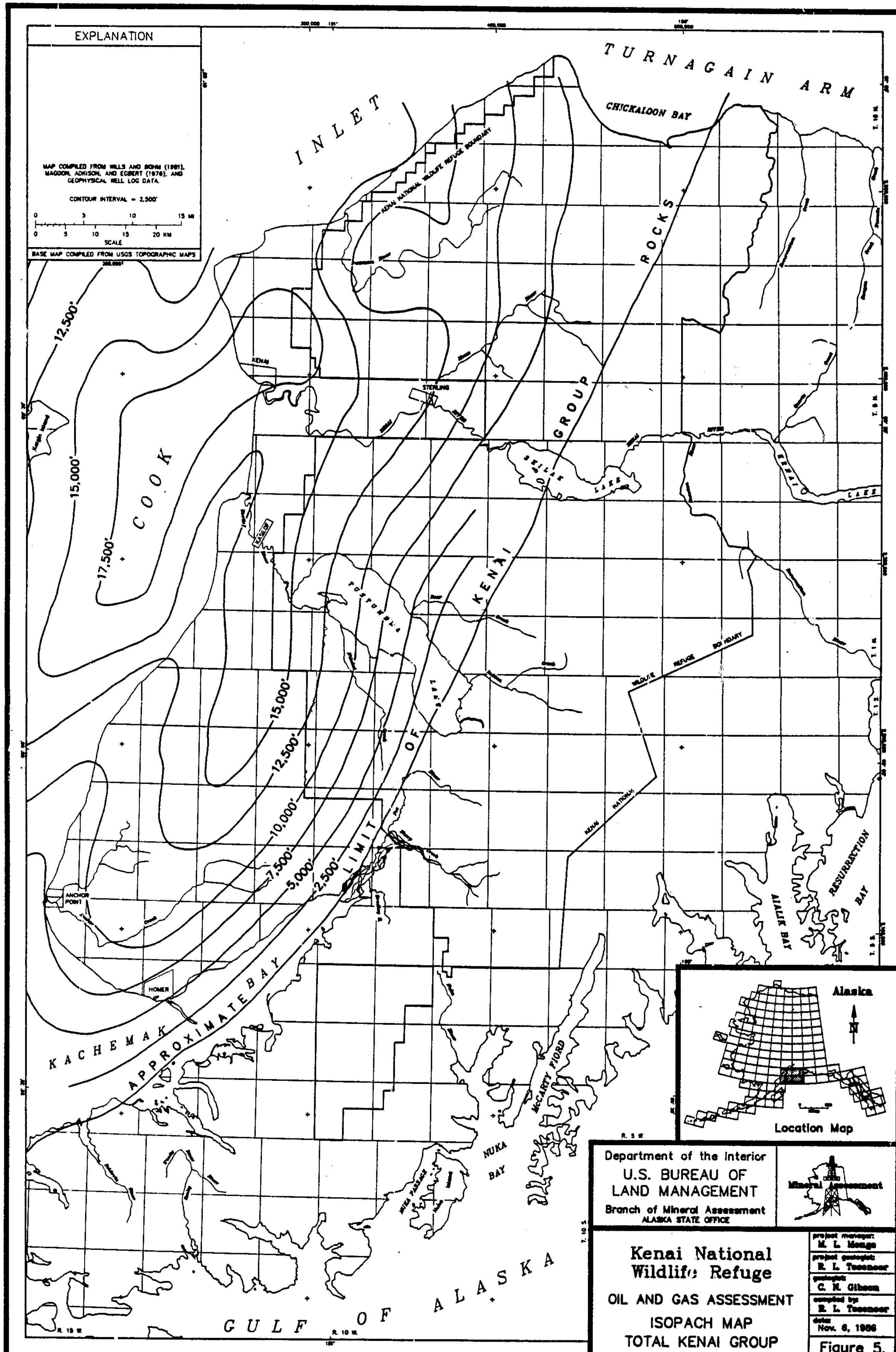
The Eocene West Foreland Formation is the oldest formation of the Kenai Group, and unconformably overlies Mesozoic rocks. The West Foreland Formation is composed of conglomerates that contain pebbles of volcanic rocks, volcaniclastic sandstones and siltstones, tuffs, and thin coal beds. Kirschner and Lyon (1973) describe the depositional environment of the West Foreland sediments as fluvial non-marine. The West Foreland Formation is from 0 to 1,700 feet (0-520 m) thick in KNWR (figure 6). The West Foreland Formation is 890 feet (270 m) thick in the Pan American West Foreland Well No. 1 (Sec. 21, T. 8 N., R. 14 W., SM), where it was first described by Calderwood and Fackler (1972). The West Foreland Formation contains up to 50 percent sandstone (figure 7)

Oligocene

The Oligocene Hemlock Conglomerate unconformably overlies the Eocene West Foreland Formation. The Hemlock Conglomerate contains from 0 to 570 feet (0-170 m) of conglomerate and conglomeratic sandstone (up to 50 percent) in KNWR (figures 8 and 9). In the Atlantic Richfield Swanson River Well No. 1 (34-10) (Sec. 10, T. 8 N., R. 9 W., SM), where it was first described by Calderwood and Fackler (1972), it is 570 feet thick. Kirschner and Lyon (1973), Boss et al (1976), and Hite (1976) have. described the depositional environment for the Hemlock Conglomerate as braided and/or meandering fluvial to deltaic to estuarine.

Upper Oligocene to Middle Miocene

The Upper Oligocene to Middle Miocene Tyonek Formation conformably overlies the Oligocene Hemlock Conglomerate. Calderwood and Fackler (1972) first described the Tyonek Formation in the Pan American Tyonek State Well No. 2 (Sec. 30, T. 11 N., R. 11 W., SM), where it is 7,695 feet of massively bedded sandstones and relatively thick subbituminous to bituminous coal beds and minor claystones and siltstones. The Tyonek Formation ranges from 0 to 7,100 feet (0-2,100 m) thick in KNWR and is up to 20 percent sandstone (figures 10 and 11). Kirschner and Lyon (1973) and Hite (1976) suggest that



EXPLANATION
MAP COMPILED FROM WILLS AND BOHM (1961), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 2,500'
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
KENAI
STERLING
SKILAK LAKE
KENAI LAKE
TUSTUMENA LAKE
LIMIT OF KENAI GROUP ROCKS
WILDLIFE REFUGE BOUNDARY
KENAI NATIONAL
12,500'
15,000'
17,500'
10,000'
7,500'
5,000'
2,500'
ANCHOR POINT
HOMER
KACHEMAK
APPROXIMATE BAY
AIALIK BAY
RESURRECTION BAY
McCARTY FIORD
NUKA BAY
GULF OF ALASKA
Alaska
Location Map
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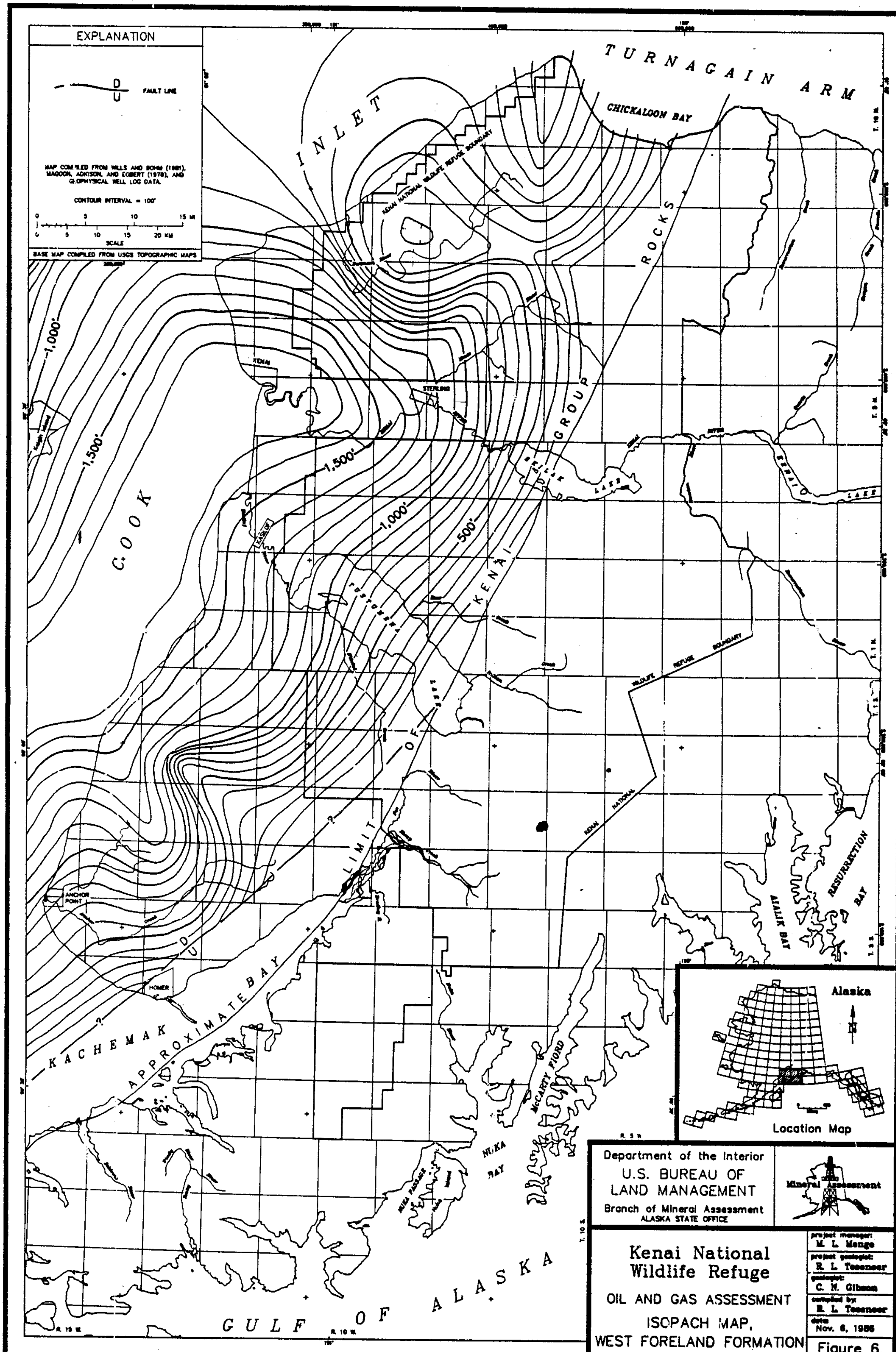
ISOPACH MAP
TOTAL KENAI GROUP
project manager: M. L. Monge
project geologist: R. L. Tessnear
geologist: C. N. Gibson
compiled by: R. L. Tessnear
date: Nov. 6, 1986
Figure 5.


EXPLANATION
FAULT LINE
MAP COMPILED FROM WILLS AND BOHM (1981), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 100'
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
ROCKS
GROUP
KENAI
LIMIT OF
APPROXIMATE
KENAI
STERLING
1,000'
1,500'
1,500'
1,000'
500'
ANCHOR POINT
HOMER
KACHEMAK BAY
WILDLIFE REFUGE BOUNDARY
KENAI NATIONAL
RESURRECTION BAY
AIALIK BAY
McCARTY FIORD
NUKA BAY
GULF OF ALASKA
Alaska
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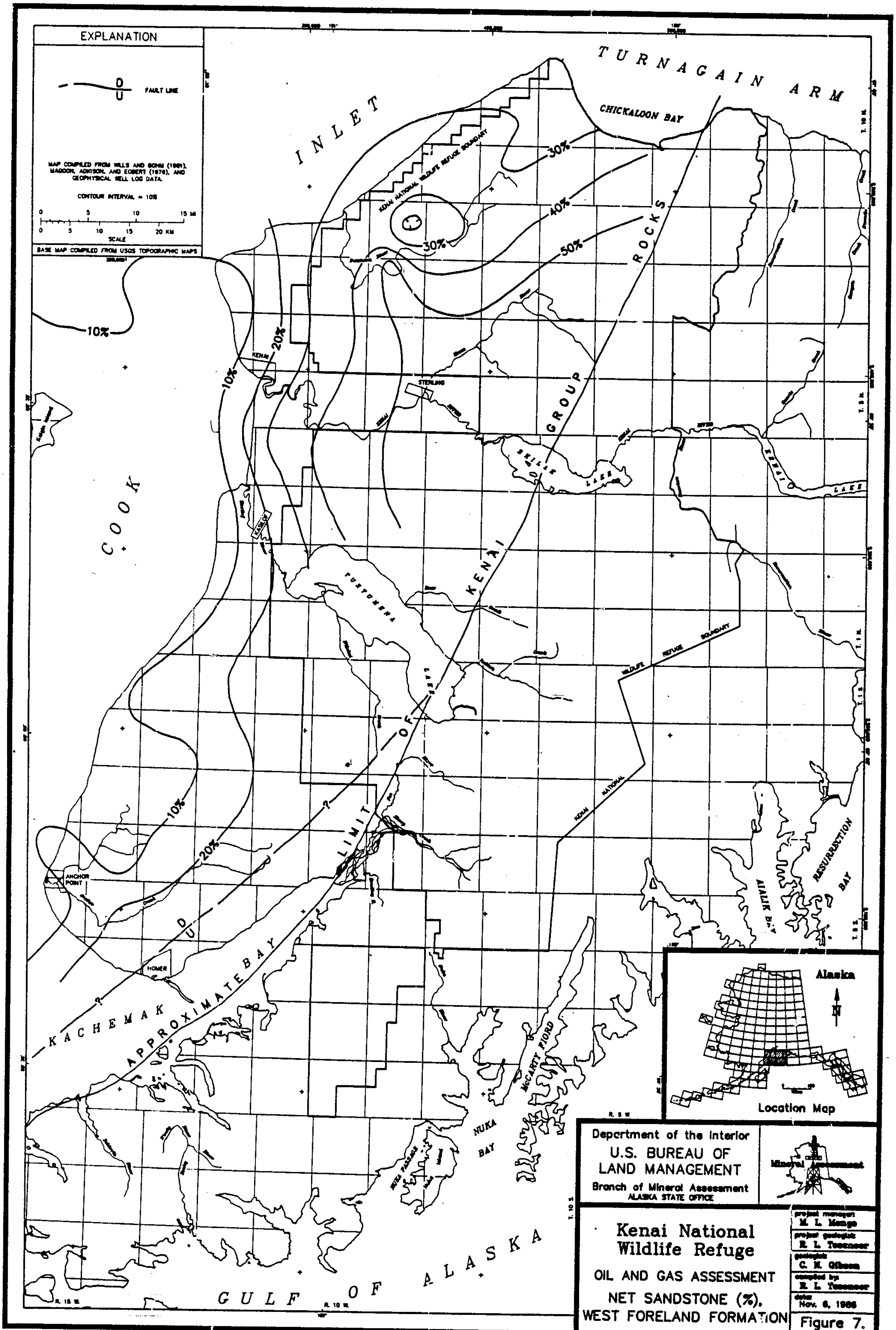
OIL AND GAS ASSESSMENT
ISOPACH MAP, WEST FORELAND FORMATION
project manager: M. L. Menge
project geologist: R. L. Tessneer
geologist: C. N. Gibson
compiled by: R. L. Tessneer
date: Nov. 6, 1986
Figure 6.


EXPLANATION
FAULT LINE
D
U
MAP COMPILED FROM WILLS AND BOHM (1981), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 10%
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
30%
40%
50%
10%
20%
KENAI
STERLING
KENAI GROUP ROCKS
SKILAK LAKE
KENAI LAKE
TUSTUMENA LAKE
LIMIT OF
APPROXIMATE
ANCHOR POINT
HOMER
KACHEMAK BAY
RESURRECTION BAY
AIALIK BAY
McCARTY FIORD
NUKA BAY
NUKA PASSAGE
GULF OF ALASKA
Alaska
N
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OIL AND GAS ASSESSMENT
NET SANDSTONE (%), WEST FORELAND FORMATION
project manager
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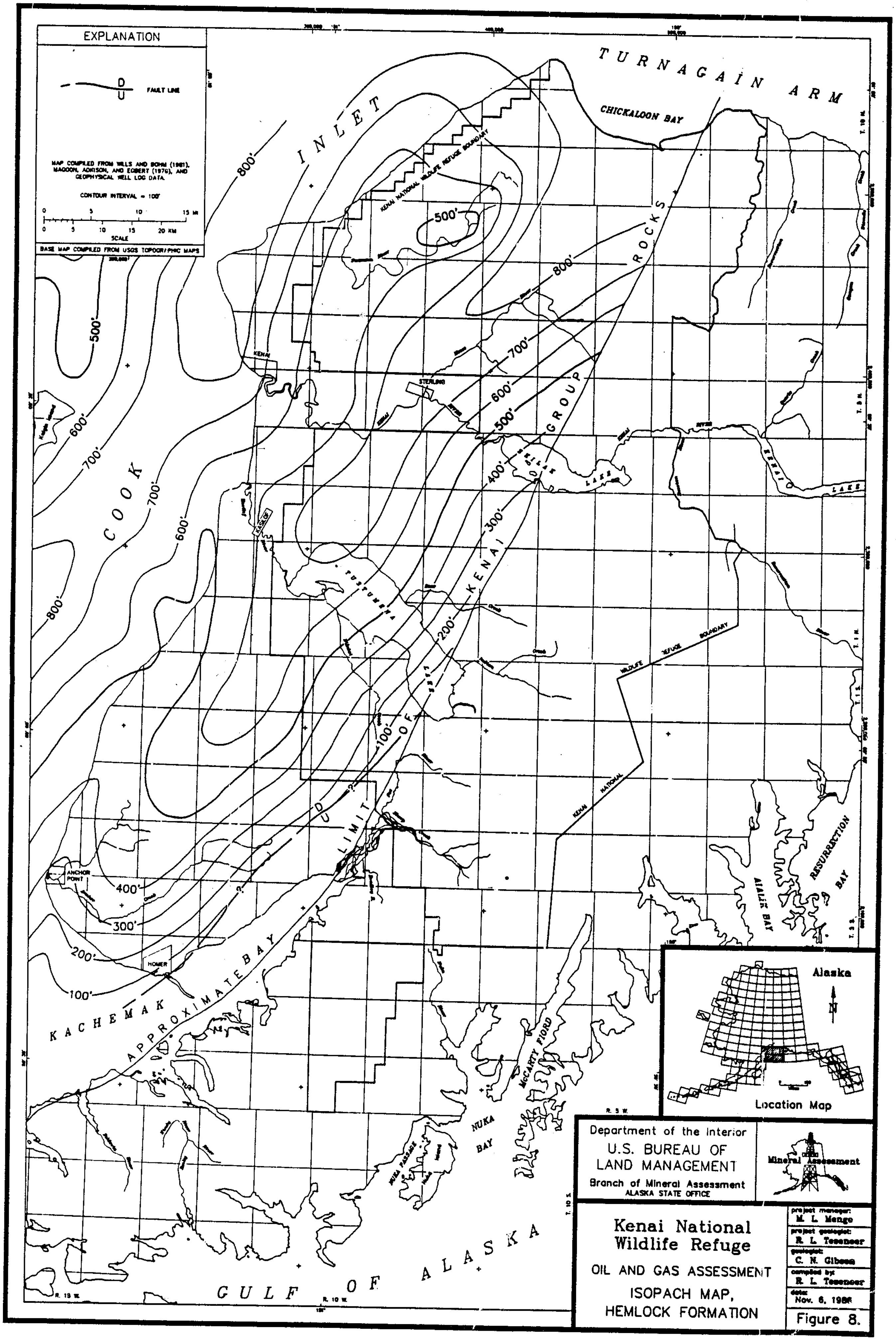
date
Nov. 6, 1986
Figure 7.

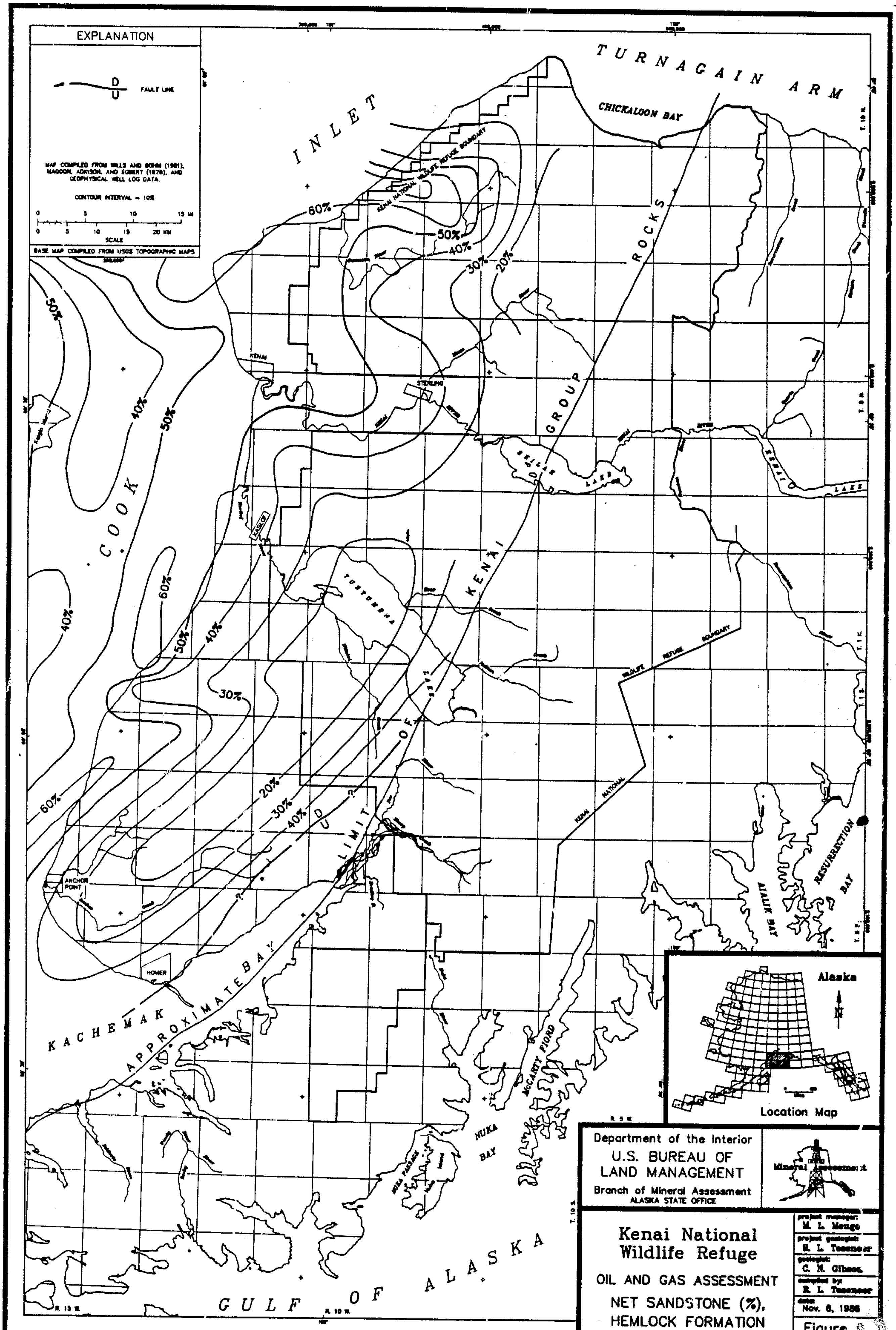


Kenai National Wildlife Refuge

OIL AND GAS ASSESSMENT

ISOPACH MAP, HEMLOCK FORMATION

Figure 8.



EXPLANATION
FAULT LINE
MAP COMPILED FROM WILLS AND BOHM (1981), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 10%
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
COOK INLET
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
KENAI GROUP ROCKS
APPROXIMATE LIMIT OF KENAI GROUP ROCKS
KENAI
STERLING
SKILAK LAKE
KENAI LAKE
TUSTUMENA
ANCHOR POINT
HOMER
KACHEMAK BAY
GULF OF ALASKA
NUKA BAY
McCARTY FIORD
AIALIK BAY
RESURRECTION BAY
60%
50%
40%
30%
20%
Alaska
Location Map
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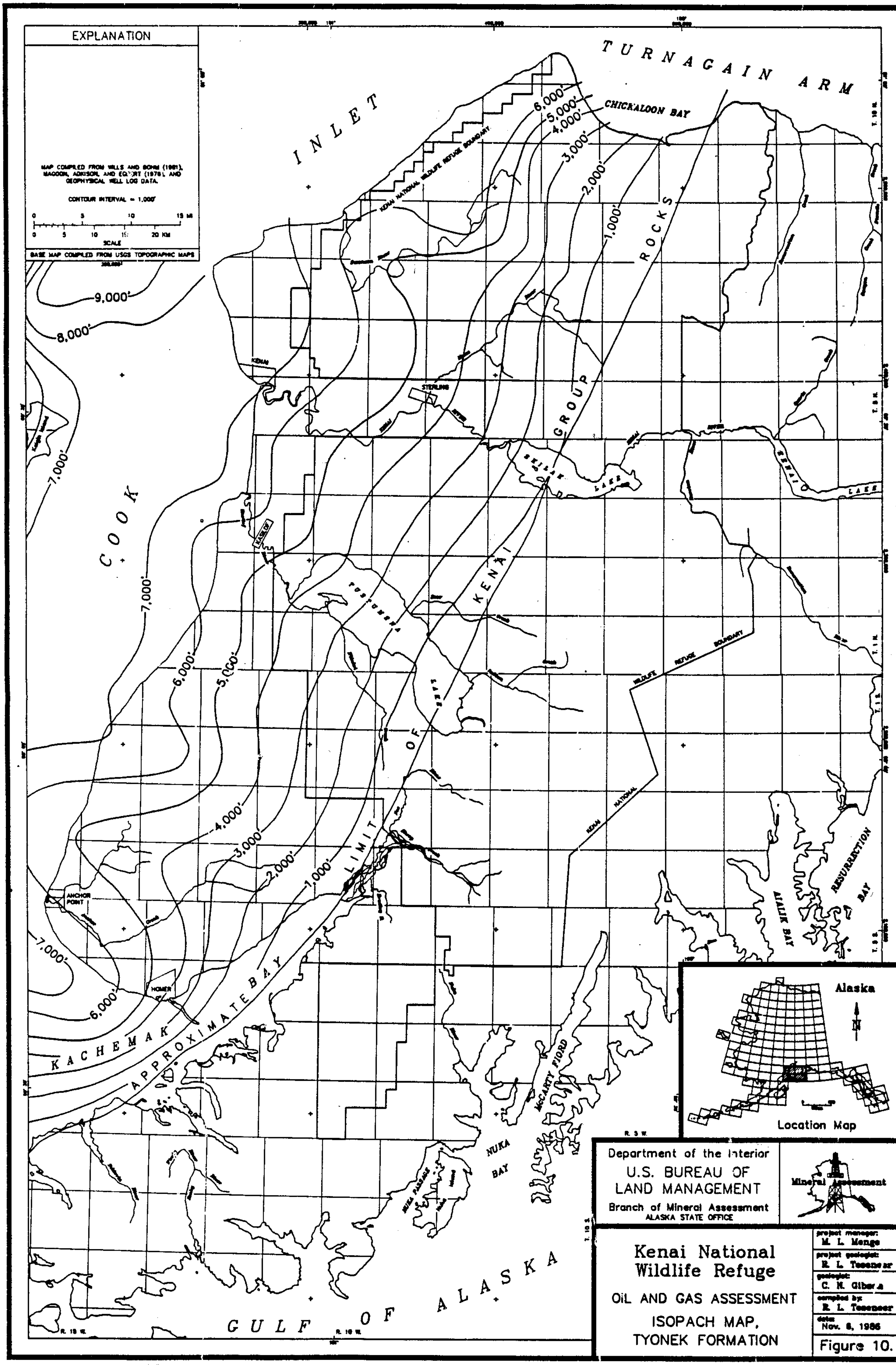
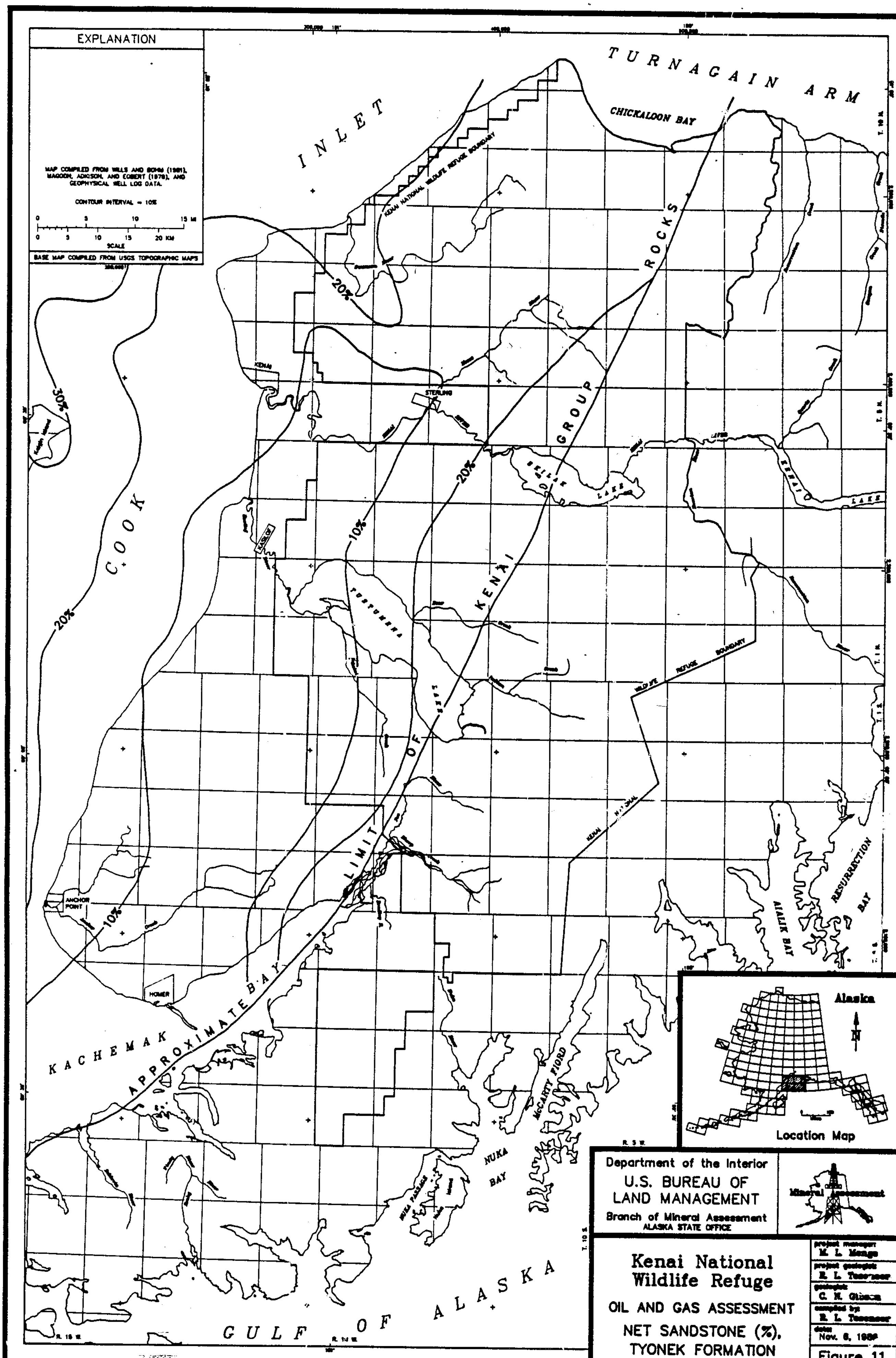
OIL AND GAS ASSESSMENT
NET SANDSTONE (%), HEMLOCK FORMATION
project manager: M. L. Menge
project geologist: R. L. Tesmer
geologist: C. N. Gibson
compiled by: R. L. Tesmer
date: Nov. 6, 1986
Figure



Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
ISOPACH MAP, TYONEK FORMATION
Figure 10.


EXPLANATION
MAP COMPILED FROM WILLS AND BOHM (1981), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 10%
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
KENAI
STERLING
KENAI GROUP ROCKS
LIMIT OF
APPROXIMATE BAY
KACHEMAK
ANCHOR POINT
HOMER
TUSTUMENA
SKILAK LAKE
KENAI LAKE
RESURRECTION BAY
AIALIK BAY
McCARTY FIORD
NUKA BAY
NUKA PASSAGE
GULF OF ALASKA
30%
20%
10%
Alaska
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Location Map
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Branch of Mineral Assessment
ALASKA STATE OFFICE
Mineral Assessment
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
NET SANDSTONE (%), TYONEK FORMATION
Nov. 6, 1985
Figure 11.

the Tyonek Formation was deposited in a fluvial deltaic and estuarine environment. Hite (1976) considers the "poorly drained alluvial basin" of the Susitna Flat to be a modern analog.

Miocene

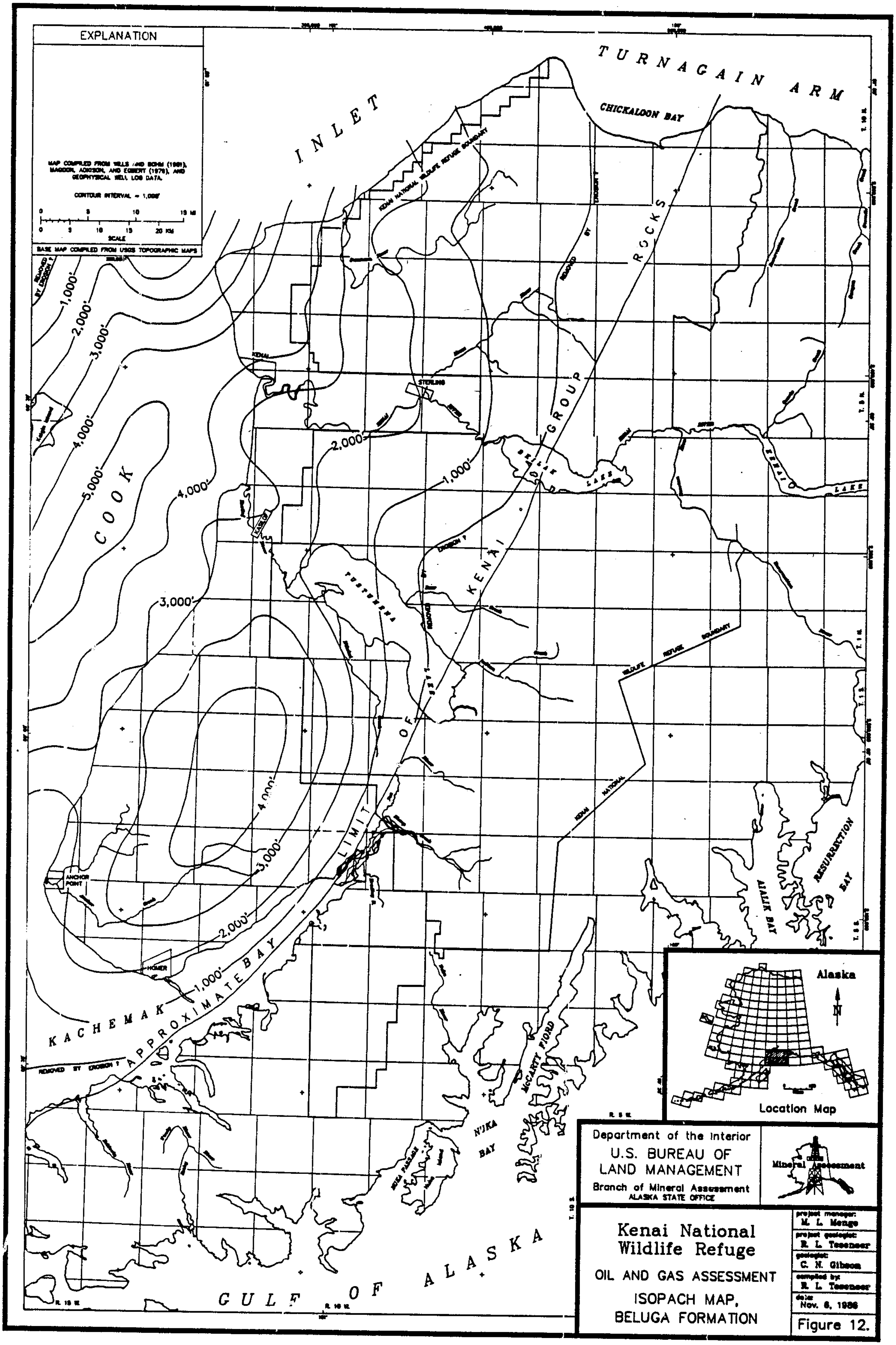
The Miocene Beluga Formation unconformably overlies the upper Oligocene to Middle Miocene Tyonek Formation. The Beluga Formation is over 3,000 feet (900 m) thick in exposures near Homer (Adkison et al, 1975b), and 4,150 feet (1,260 m) thick in the Standard Oil (Chevron) Beluga River Well No. 1 (Sec. 35, T. 13 N., R. 10 W., SM) where it was first described by Calderwood and Fackler (1972). Figures 12 and 13 show that the Beluga Formation ranges from 0 to 4,400 feet (0-1,300 m) thick in KNWR, with up to 45 percent sandstone. The Beluga River Formation consists of interbedded sandstones, siltstones, and claystones, with thin beds (less than 6 feet (2 m) of lignitic to subbituminous coal. Thick conglomeratic sandstones (fanglomerates) occur locally. The sandstones are generally laterally continuous. Sedimentary structures within the sandstones indicate a variable flow regime indicative of a braided stream environment with coalescing alluvial fans (Kirschner and Lyon, 1973; Hayes et al, 1976). Heavy mineral suites from the sandstones indicate that the Kenai Chugach Mountains are the source of the Beluga sediments (Hayes et al, 1976).

Pliocene

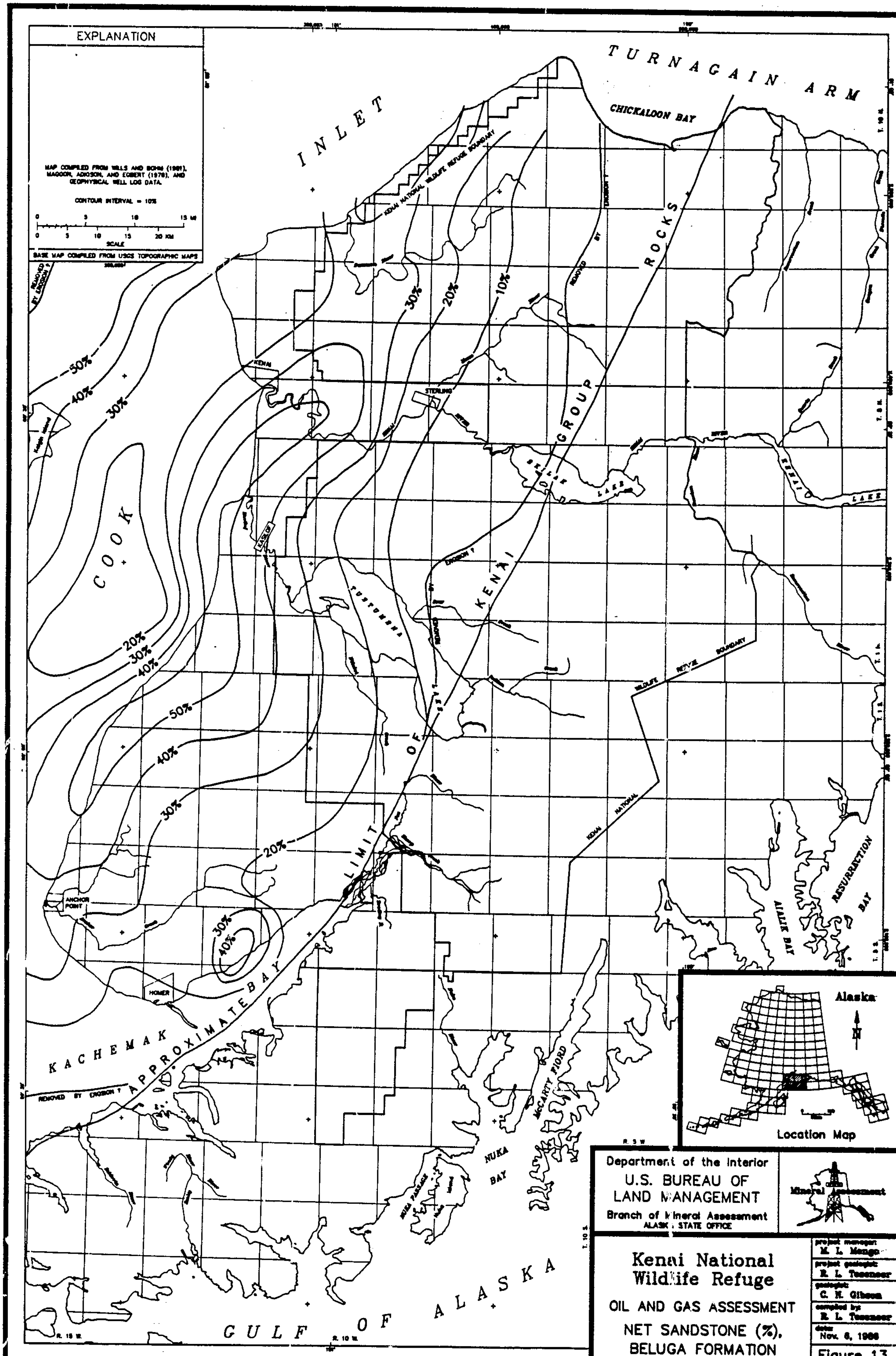
The Pliocene Sterling Formation unconformably overlies the Miocene Beluga Formation. The Sterling Formation is characterized by fining upward sequences of conglomerates (rare), conglomeratic sandstones and massive coarse- to fine-grained sandstones. These sequences are commonly 30 to 90 feet (9 to 27 m) thick and are overlain by siltstones, claystones, tuffs, and thin coals. The fining upward sequences are repetitive and can be traced laterally over large distances. They are indicative of meandering point bar sequences (Hayes et al, 1976). The Sterling Formation ranges from 0 to 6,200 feet (0-1,900 m) thick in KNWR (figure 14), and is 4,490 feet (1,370 m) thick in the Union Oil Sterling Unit Well No. 23-15 (Sec. 15, T. 5 N., R. 10 W., SM) where it was first described by Calderwood and Fackler (1972). The sandstone composition of the Sterling Formation indicates that its primary source was the Alaska-Aleutian Range batholith (Hayes et al, 1976; Hite, 1976).

Quaternary and Recent

Pleistocene and Holocene glacial sediments and alluvium conformably overlie the Tertiary Kenai Group. This thin veneer of sediment is labelled "Q" on plate 1.

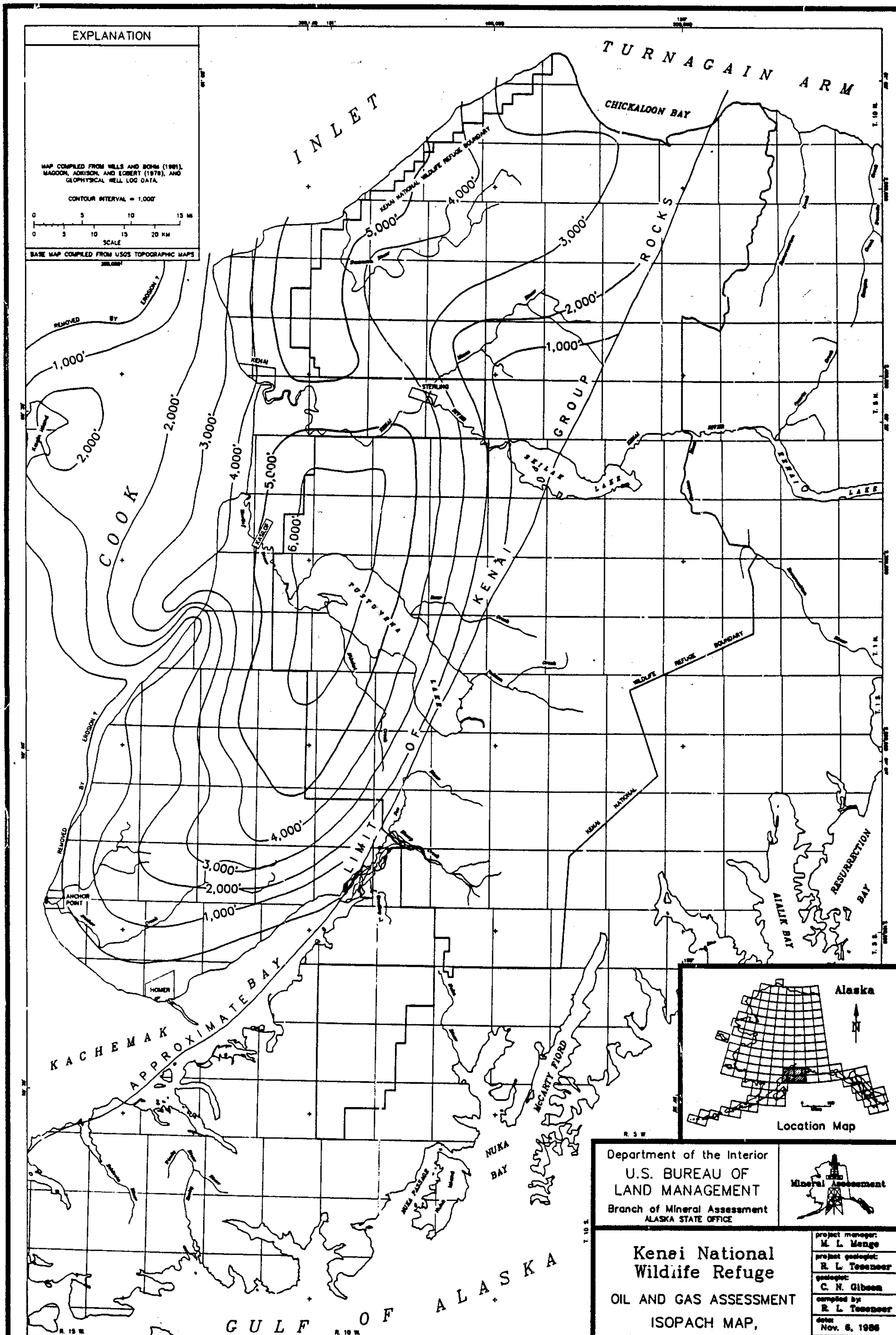


EXPLANATION
MAP COMPILED FROM WILLS AND BOHM (1991), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 1,000'
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
KENAI
STERLING
KENAI GROUP ROCKS
REMOVED BY EROSION ?
SKILAK LAKE
KENAI LAKE
TUSTUMENA
LIMIT OF
APPROXIMATE BAY
ANCHOR POINT
HOMER
KACHEMAK
1,000'
2,000'
3,000'
4,000'
5,000'
AIALIK BAY
RESURRECTION BAY
McCARTY FIORD
NUKA BAY
NUKA PASSAGE
GULF OF ALASKA
Alaska
N
Location Map
Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE
Mineral Assessment
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
ISOPACH MAP, BELUGA FORMATION
project manager: M. L. Menge
project geologist: R. L. Tessneer
geologist: C. N. Gibson
compiled by: R. L. Tessneer
date: Nov. 6, 1986
Figure 12.



EXPLANATION
MAP COMPILED FROM WILLS AND BOHM (1981), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 10%
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KACHEMAK
BAY
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
LIMIT OF KENAI GROUP ROCKS
APPROXIMATE
REMOVED BY EROSION ?
KENAI
STERLING
ANCHOR POINT
HOMER
SKILAK LAKE
KENAI LAKE
TUSTUMENA
RESURRECTION BAY
AIALIK BAY
MCCARTY FIORD
NUKA BAY
GULF OF ALASKA
50%
40%
30%
20%
10%
Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE
Mineral Assessment
Alaska
Location Map
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
NET SANDSTONE (%), BELUGA FORMATION
project manager: M. L. Menge
project geologist: R. L. Tessmer
geologist: C. N. Gibson
compiled by: R. L. Tessmer
date: Nov. 6, 1986

Figure 13.



Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
ISOPACH MAP, STERLING FORMATION

Figure 14.

Structural Geology and Tectonics

Structure

There are two major structural features that occur within or that are partially within KNWR. The Border Ranges Fault cuts across the refuge from the southwest to the northeast, and the western two-thirds of the refuge lies on the southeastern flank of the Cook Inlet Basin.

The Border Ranges Fault is actually a fault zone that is the major tectonic boundary between two geologic terranes. The Border Range Fault is a series of high-angle reverse faults that dip to the southeast (MacKevett and Plafker, 1974). The fault zone can be traced from Kodiak Island northeastward to the St. Elias Mountains in southeastern Alaska. The Eagle River and Knik thrust faults are parts of the Border Ranges Fault Zone. This fault zone forms the southeastern margin of the Cook Inlet Basin.

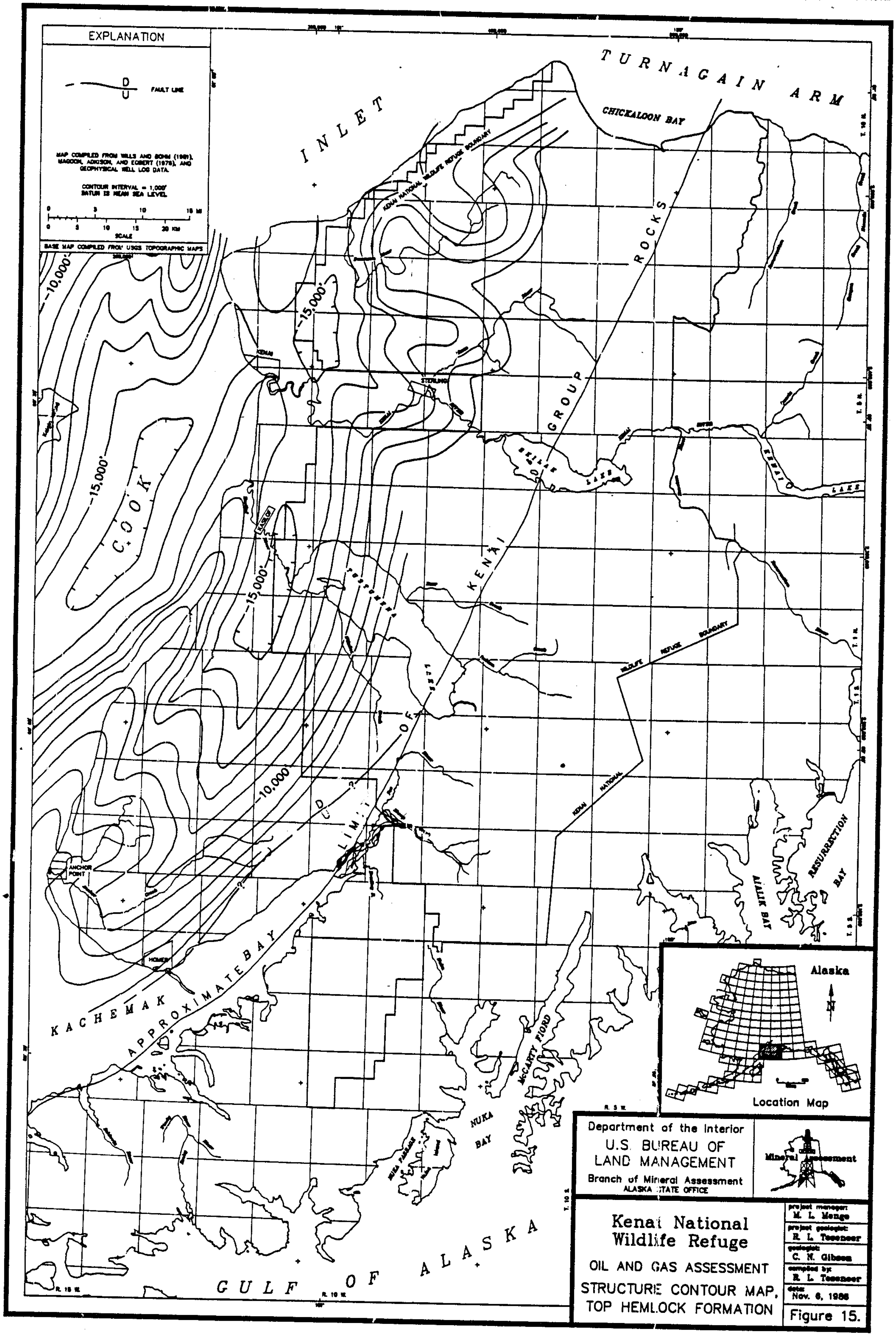
The Cook Inlet Basin is a relatively narrow, elongated, northeast-trending, sedimentary basin. It is approximately 200 miles (320 Km) long and 60 miles (97 Km) wide, and is divided geographically into the upper and lower basin at Kalgin Island. The deepest part of the basin is under Cook Inlet. The floor of the basin becomes shallower to the southeast. Figure 15 is the structure map of the Hemlock Formation, and it generally reflects the rising basement to the southeast of Cook Inlet. The Bouger gravity map of the area also shows this trend (figure 16).

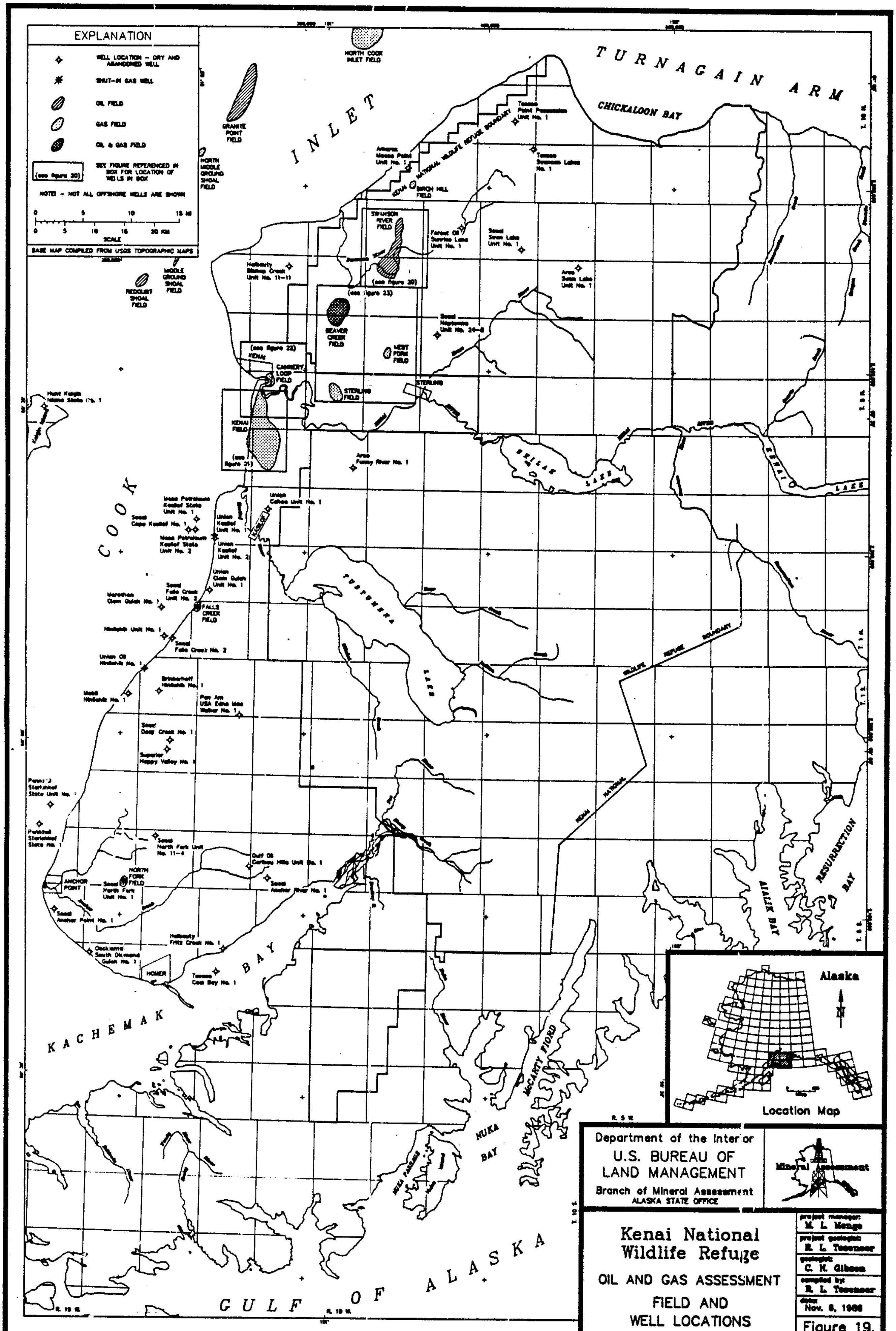
The rocks of the Kenai Range that underlie the eastern one-third of the refuge are complexly folded and faulted. Compared to the faults of the Border Ranges Fault Zone, these are all relatively minor features.

The rocks of the Cook Inlet Basin that underlie KNWR are deformed by a series of northest trending anticlines and synclines with minor crosscutting faulta; at least in the Swanson River Field.

Tectonics

Presently, the Cook Inlet region is part of a tectonically active, convergent continental margin. The Aleutian trench, a deep trench that extends from the eastern Gulf of Alaska, paralleling the Alaska Peninsula and along the Aleutian Islands (fig. 17), reflects the boundary of the convergent margin; here the Pacific plate is being underthrust or subducted beneath the North American Plate. As a result of this subduction process across the margin, the area is subject to earthquakes of varying intensity generated from the Benioff zone, a seismic zone that dips northeast (inclined downward from the trench) and marks the zone of subduction of the Pacific Plate beneath southcentral Alaska (Lahr et al, 1974). The largest earthquake in recent times occurred on Good Friday, March 1964, causing the Cook Inlet and the Kenai Peninsula to subside and the floor of the Gulf of Alaska to rise (Plafker, 1969 and 1972).


EXPLANATION
FAULT LINE
MAP COMPILED FROM WILLS AND BOHM (1961), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 1,000'
DATUM IS MEAN SEA LEVEL
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
ROCKS
GROUP
KENAI
OF
LIMIT
APPROXIMATE
KACHEMAK BAY
-10,000'
-15,000'
-10,000
KENAI
STERLING
ANCHOR POINT
HOMER
SKILAK LAKE
KENAI LAKE
RESURRECTION BAY
AIALIK BAY
McCARTY FIORD
NUKA BAY
GULF OF ALASKA
Alaska
N
Location Map
Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE
Mineral Assessment
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
STRUCTURE CONTOUR MAP, TOP HEMLOCK FORMATION
project manager: M. L. Menge
project geologist: R. L. Tessener
geologist: C. N. Gibson
compiled by: R. L. Tessener
date: Nov. 6, 1986
Figure 15.



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ALASKA STATE OFFICE

Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
FIELD AND WELL LOCATIONS

project manager: M. L. Menge
project geologist: R. L. Tessmer
geologist: C. N. Gibson
compiled by: R. L. Tessmer
date: Nov. 6, 1986

Figure 19.

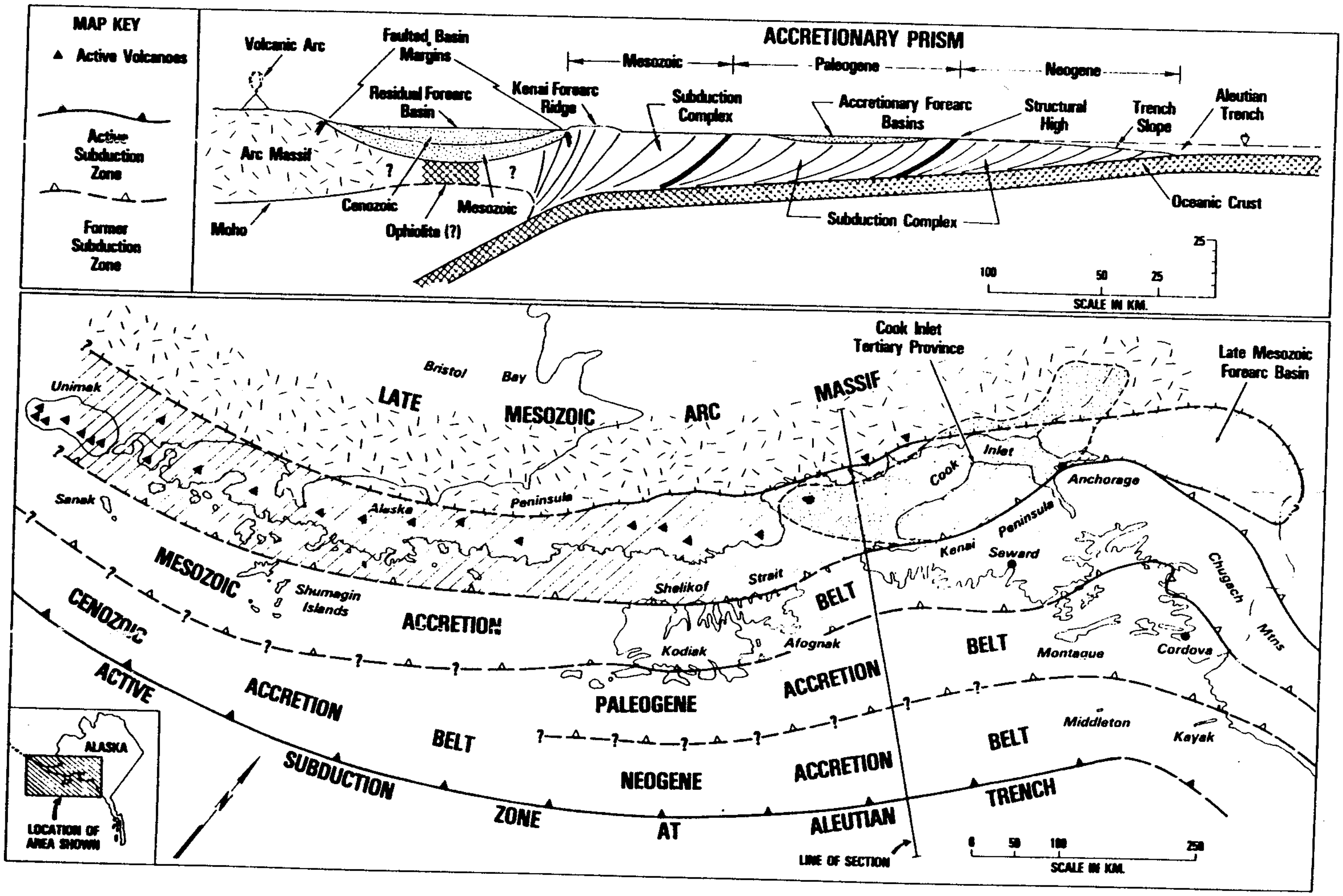


Figure 17. Map and cross section of a convergent continental margin, along the Aleutian Trench (after Dickinson and Seely, 1979).

allochthonous oceanic and continental terranes (tectonostratigraphic terrane) (Jones et al, 1981; von Huene et al, 1985) (fig. 18) that were emplaced in their present position as coherent microplates no later than Late Cretaceous to Early Tertiary time (Moore, 1983). Briefly, the Upper Paleozoic to Lower Jurassic rocks exposed on the Alaska Peninsula (Peninsular terrane) are believed to be accreted from equatorial sources (Coe et al, 1985). The Upper Jurassic (?) to Cretaceous melange and flysch deposits of the Kenai-Chugach Mountains (Chugach terrane) have been shown to have been displaced from about 25° south of their present location 62 M.A., based upon paleomagnetic data of early Tertiary igneous intrusive rocks interbedded with sedimentary rocks (Coe et al, 1985). Therefore, in a general sense, the continuous accretionary margin in the Gulf of Alaska and Cook Inlet region is believed to have started in an initial subduction in the southern hemisphere, then moved across the Pacific on the Kulu Plate to collide with central North America and then northwestward on the Kulu Plate to collide with Alaska along an early eastern Aleutian trench during the Late Tertiary, then began the subduction along the present-day Aleutian Trench. The Cook Inlet Tertiary Basin assumed its present character during the Oligocene as the Kenai Group began accumulating.

Historical Geology

The discussion of the geologic history of KNWR will start in the Late Triassic, as little is known about the area prior to that time.

During the Late Triassic, the KNWR area was on a stable marine shelf, as indicated by marine siltstones, cherts, and limestones. Submarine volcanic activity began near the end of the Triassic as the area became tectonically active.

Volcanic activity intensified into the Early Jurassic. Volcanic islands were scattered through the area. Near the end of the Early Jurassic, volcanic activity decreased, but some explosive volcanism was initiated as indicated by some thinly bedded tuffs (Detterman and Hartsock, 1966). This area was a typical volcanic island arc, similar to the Aleutian Islands today. Volcanism ceased by the end of the Lower Jurassic.

Deposition of the McHugh Complex rocks began during the Jurassic, at some distance to the southeast of KNWR (Magoon, 1986).

There was either a pause in deposition or a brief period of erosion in KNWR at the end of the Lower Jurassic and the beginning of the Middle Jurassic. This probably corresponded to the uplift of the Alaska-Aleutian Range batholith to the west of KNWR. When sedimentation resumed, the batholith was the source of the shallow marine sediments of the Tuxedni Group and the Chinitna Formation (Fisher and Magoon, 1978). The topography around KNWR in the Middle Jurassic was probably similar to today's, with rugged mountains and short streams with high gradients carrying coarse sediments into a shallow marine environment. There were several periods of marine transgression and regression in the Middle Jurassic. The sediments being deposited were much finer by the end of the Middle Jurassic as the elevation of the highlands was decreased by erosion.

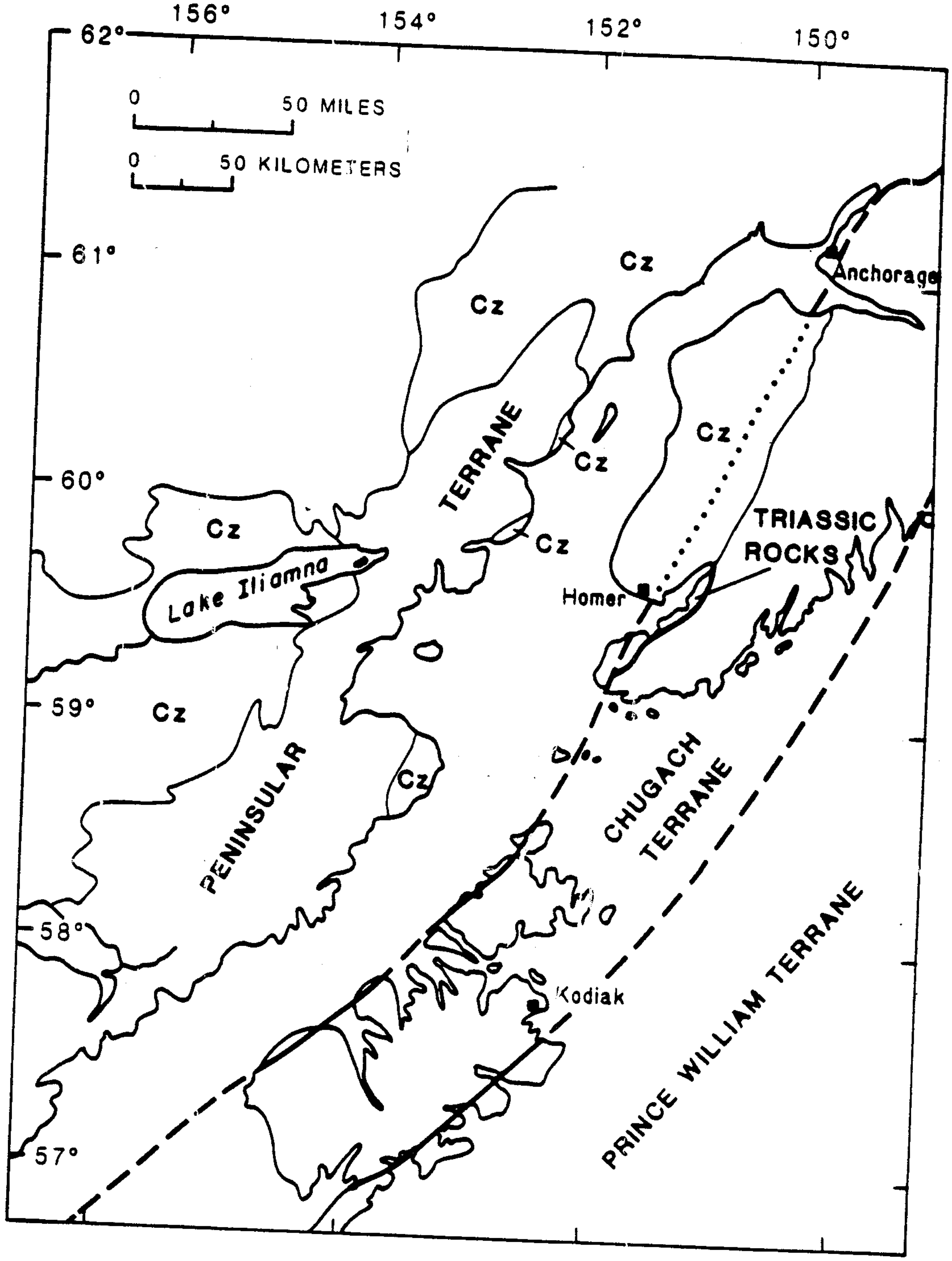


Figure 18. Tectono-stratigraphic terranes of the Cook Inlet Basin (after Magoon and Egbert, 1986).

Uplift at the beginning of the Upper Jurassic provided the sediments for the Naknek Formation. Erosion continued through the Upper Jurassic with sedimentation in a shallow marine environment.

During the Lower Cretaceous, this area experienced a period of non-deposition. The only rock unit possibly deposited during the Lower Cretaceous is the Herendeen Limestone. The rocks of this formation imply that the Lower Cretaceous was a time of regional stability, with the area KNWR being a shallow marine shelf. During this time, the McHugh Complex accreted to the continent (Fisher and Magoon, 1978).

Subduction resumed to the southeast of KNWR in the Upper Cretaceous (Magoon, 1976). A marine transgression during the Upper Cretaceous is recorded in the rocks of the Matanuska/Kaguyak Formation. The Valdez Group was emplaced against the McHugh Complex at about this time.

The Cenozoic era in the Cook Inlet Basin, marked an abrupt change in sedimentation with a switch from marine shelf deposits to nonmarine forearc basin deposits. Plutonism occurred between 40 to 25 M.A.

During the Paleocene, subduction at the trench uplifted the basin and thrust the older McHugh Complex over the younger Valdez Group. This uplift of the basin caused site deposition of the volcaniclastic sediments, siltstone, and graywacke of the West Foreland Formation (Fisher and Magoon, 1978).

The Middle Eocene through Lower Oligocene was a period of non-deposition and erosion. Near the end of the Oligocene, the basin was a half to full graben bounded by highlands that contributed very little sediment. The Hemlock Conglomerate and overlying Tyonek Formation contain heavy mineral suites that suggest a northern source, such as east-central Alaska or western Canada, for these sediments (Kirschner and Lyon, 1973). The uplift of the central Alaska Range cut off the source for the Tyonek Formation.

During the upper Miocene, the source for the Beluga Formation was from the Kenai-Chugach Range. The Alaska Range was the source for the Sterling Formation during the Pliocene and Pleistocene.

Five periods of Quaternary glaciation affected the Cook Inlet Basin. The most recent ended only 1,100 years ago. Subduction along the trench continues through the present.

Geochemistry

The lack of sufficient geochemical data from the Cook Inlet Basin makes it difficult to obtain a satisfactory understanding of the petroleum geochemistry of the area. Most of the oil, discovered to date, occurs in the northern half of the basin, while most of the adequate geochemical data is from the southern half. To further complicate the geochemistry of the basin, the gas in the basin has a different source than the oil.

Oil Geochemistry

From the available data, the only viable sources for oil are the marine rocks of the Middle Jurassic (Tuxedni Group) (Claypool, 1986; Magoon and Claypool, 1977, 1981; Espenschied, personal communication, 1986). Claypool (1986) and Magoon and Claypool (1977, 1978) state that the rocks of the Tuxedni Group are the only ones known to have the proper type of organic material and also the proper burial history (thermal maturity) for the production of oil. No direct link can be shown between the known oil occurrences and possible source rocks; therefore, one must not rule out the possibility of as yet unidentified source rocks within the basin.

Gas Geochemistry

Two types of gas are found within the Cook Inlet Basin, associated and nonassociated. Associated gas is found only at oil fields and is associated with liquid hydrocarbons. Nonassociated gas is found higher in the section and is not associated with liquid hydrocarbons.

Carbon isotope data and hydrocarbon composition (C_1/C_1-C_5) indicate that the associated gas is thermogenic in nature, while the nonassociated gas is biogenic in nature with a possible minor thermogenic component (of a different source than that of the associated gas). The associated gas formed through thermal decomposition of kerogen in the same source rocks as the source of the liquid hydrocarbons and possibly even from thermal decomposition of the liquid hydrocarbons. The nonassociated gas formed through biologic activity. It is possible that there is a minor component of thermogenic gas in the nonassociated gas that formed from the thermal decomposition of coal (Claypool, Threlkeld, and Magoon, 1980).

Description of Oil and Gas Resources

Known Oil and Gas Fields (Regional)

Alaska has two oil and gas production areas. One is the Cook Inlet Basin, and the other is the Arctic North Slope. The oil and gas fields of the Cook Inlet Basin are discussed below. The fields of the North Slope are not related to KNWR and, therefore, are not discussed.

Known Oil and Gas Fields (Local)

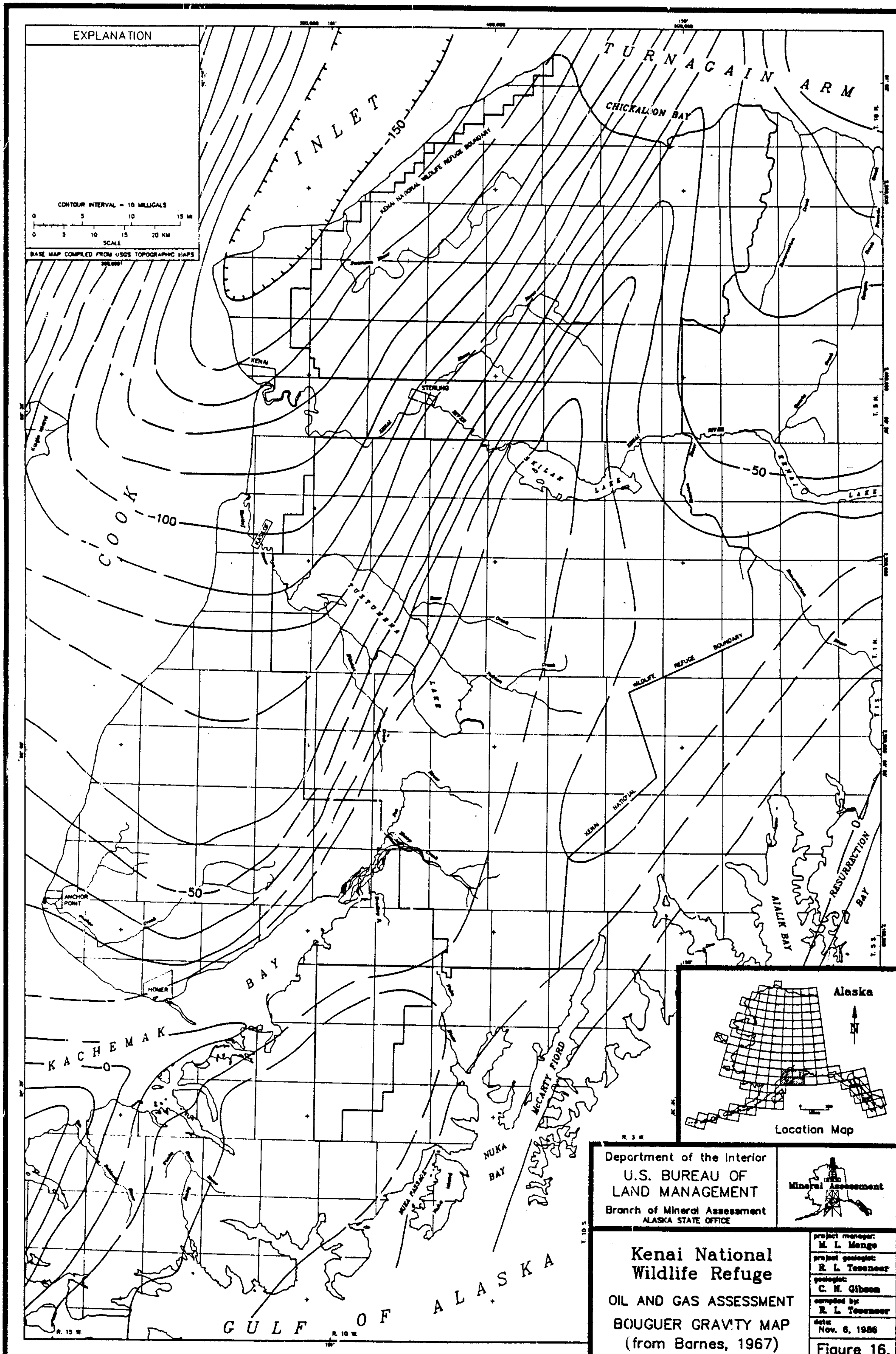
A portion of KNWR lies within the Cook Inlet Tertiary Petroleum Province, which has been classified as a Favorable Petroleum Geological Province (FPGP).

Kenai Peninsula Fields

Figures 19 through 23 show all of the wells and fields on the Kenai Peninsula and some of the wells of the offshore Cook Inlet area, and table 1 lists the productive horizons for each of the Cook Inlet Basin fields.

AGE		TERTIARY					
ROCK UNIT	PERIOD						
	GROUP	KENAI GROUP					
	FORMATION	STERLING FORMATION	BELUGA FORMATION	TYONEK FORMATION		HEMLOCK CONGLOMERATE	WEST FORELAND FORMATION
	MEMBER			CHUITNA MEMBER	MIDDLE GROUND SHOAL MEMBER		
Oil Fields	Beaver Creek				0		
	Granite Point				0	0	
	McArthur River				0	0	0
	Middle Ground Shoal				0	0	
	Redoubt Shoal					0	
	Swanson River					0	
	Trading Bay				0	0	
Gas Fields	Albert Kaloa			*			
	Beaver Creek	*	*				
	Beluga River	*	*				
	Birch Hill				*		
	Falls Creek				*		
	Ivan River			*			
	Kenai	*	*		*		
	Lewis River		*				
	McArthur River			*	*		
	Middle Ground Shoal				*		
	Moquawkie			*	*		
	Nicolai Creek		*	*			
	North Cook Inlet	*	*		*		
	North Fork				*		
	North Middle Ground Shoal				*		
	Sterling	*					
	Stump Lake		*				
	Swanson River	*			*		
	Theodore River		*				
	Trading Bay				*		
	West Foreland				*		
	West Fork	*					

Table 1. Productive horizons, by field, in the Cook Inlet Basin (from AOGCC, 1985).



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project manager: M. L. Menge
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compiled by: R. L. Tessneer
date: Nov. 6, 1986

Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
BOUGUER GRAVITY MAP
(from Barnes, 1967)

Figure 16.

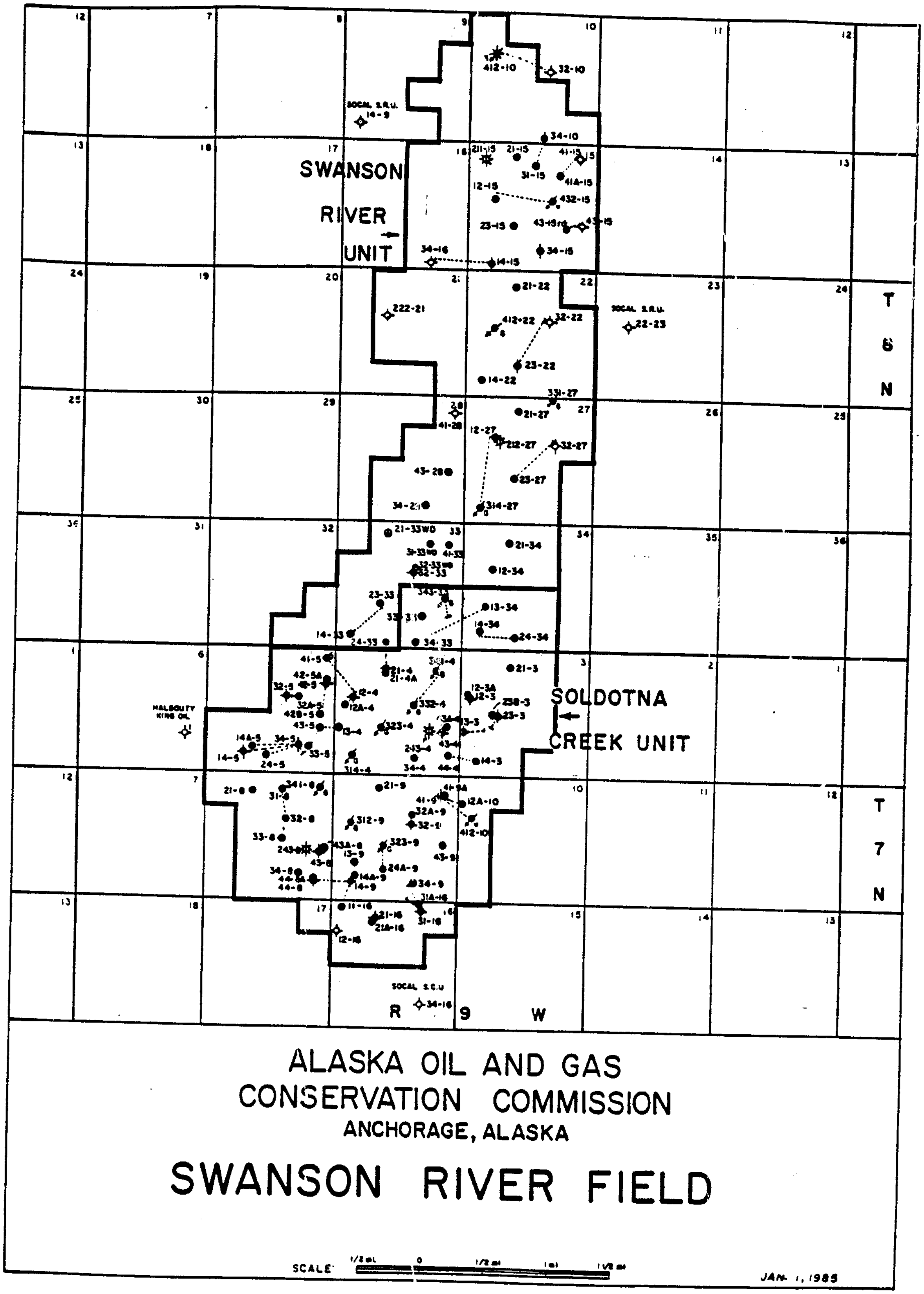


Figure 20. Well locations in and near Swanson River Field (from AOGCC, 1985).

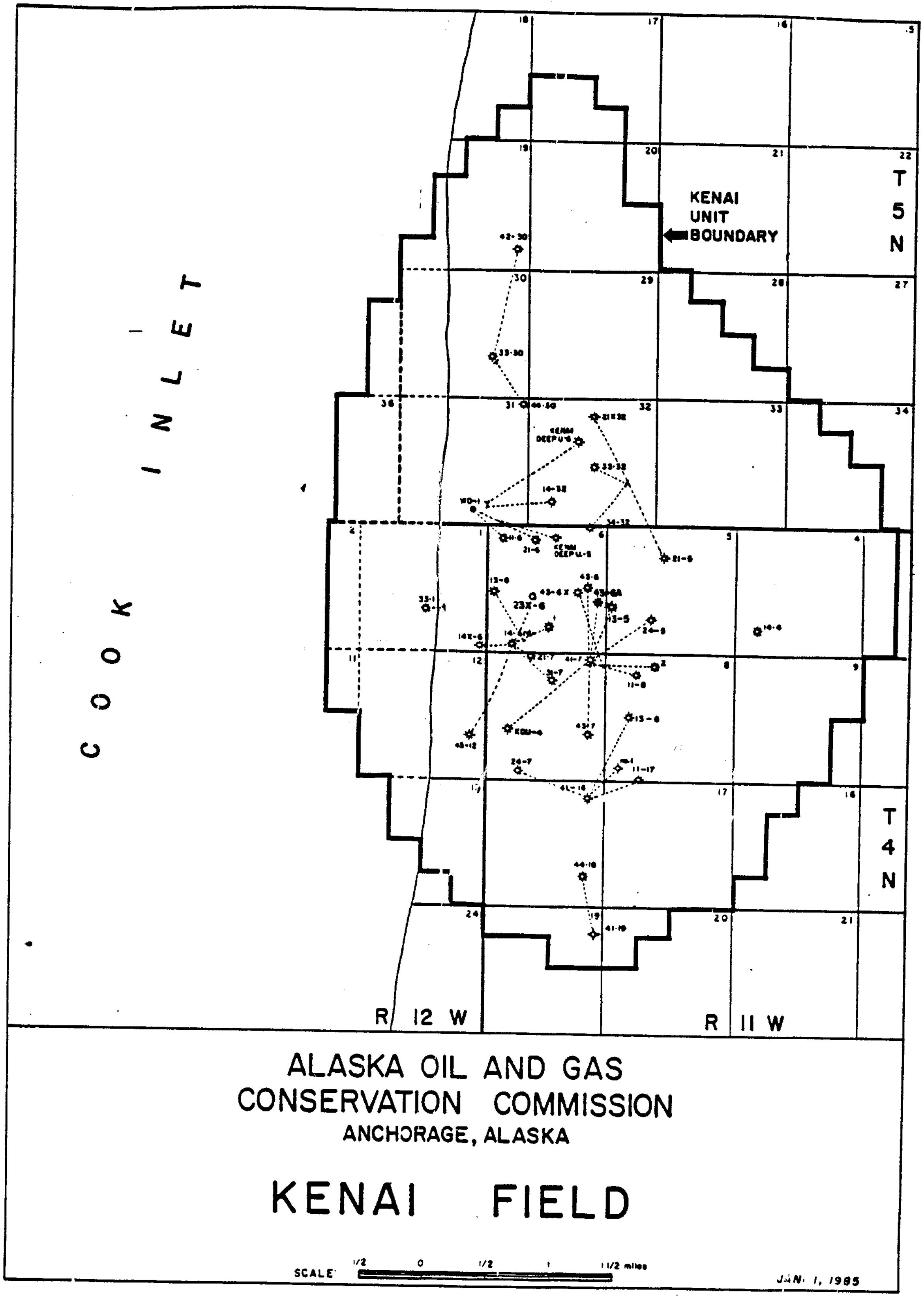


Figure 21. Well locations in and near Kenai Field (from AOGCC, 1985).

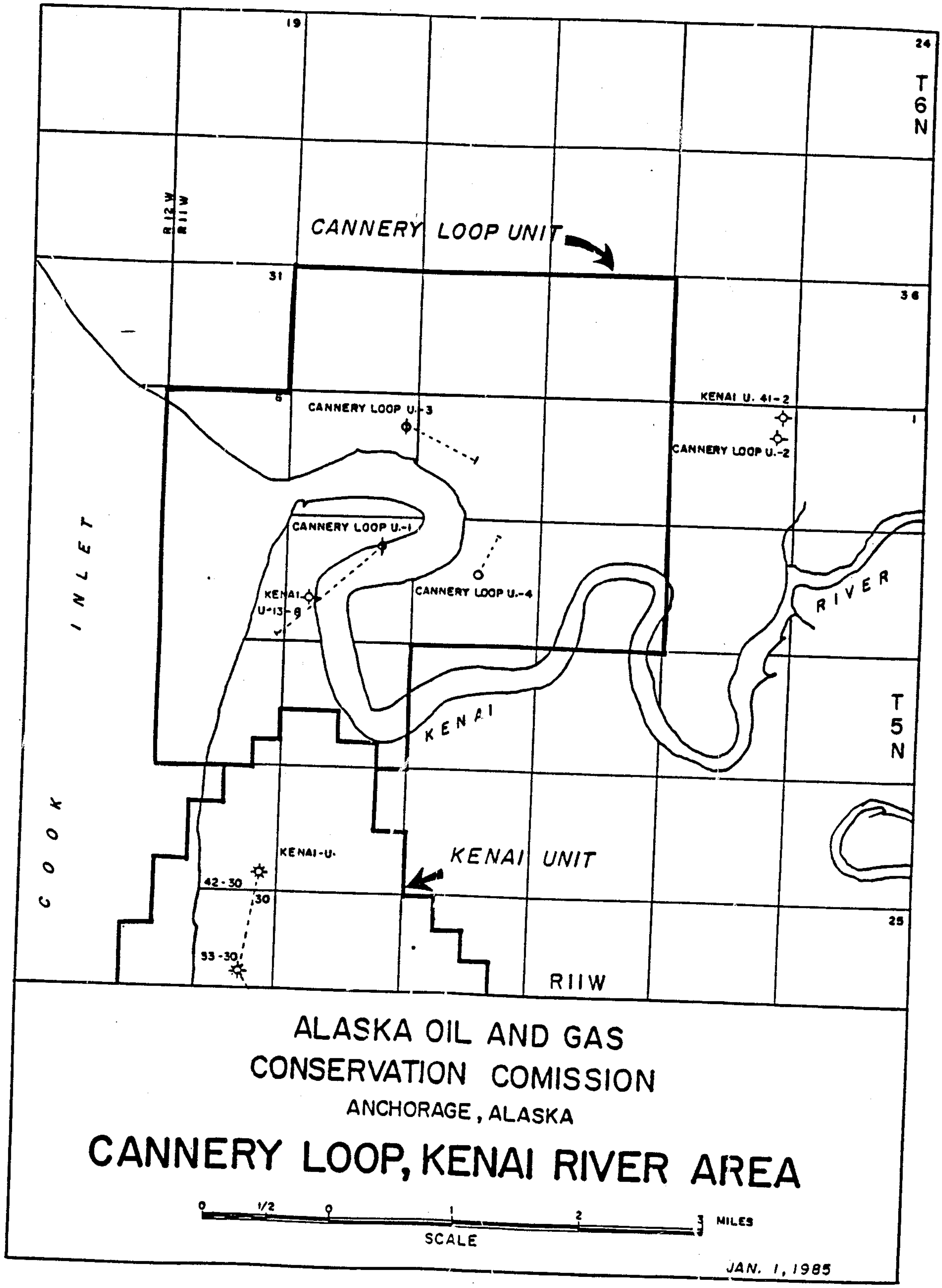


Figure 22. Well locations in and near Cannery Loop Field (from AOGCC, 1985)

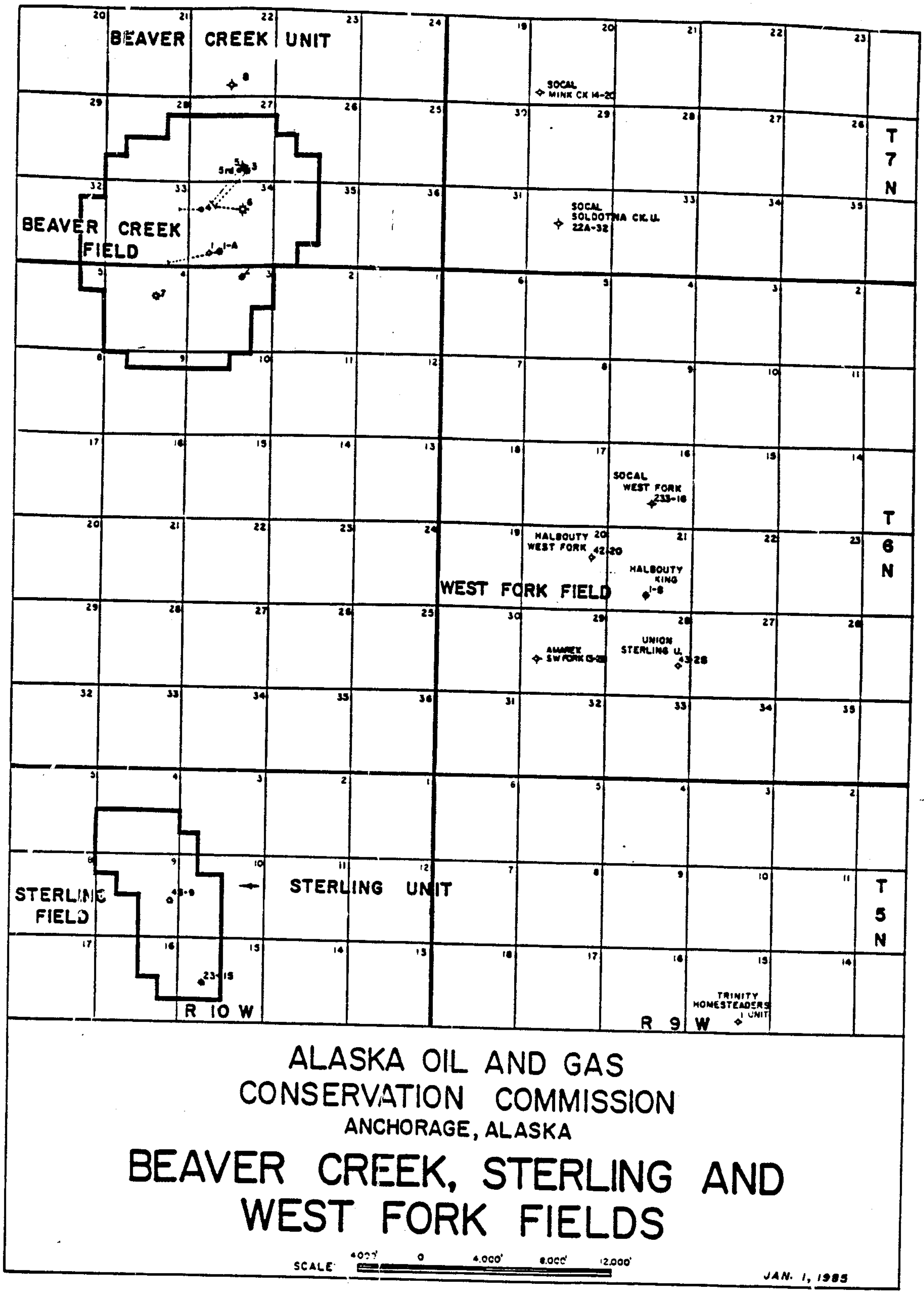


Figure 23, Well locations in and near Beaver Creek, Sterling, and West Fork Fields (from AOGCC, 1985).

Appendix B lists all Kenai Peninsula wells and gives the location, total depth, dates drilled, and status of each well, if known.

The Swanson River Field was discovered on July 19, 1957, by Atlantic Richfield Oil Corporation (ARCO). Swanson River Well No. 1 (34-10) was the discovery well. This was the first major discovery in Alaska. The well had a sustained production of 900 barrels per day of 30° API gravity oil. The original oil in place was estimated at 520 million stock tank barrels. More than 200 million barrels have been produced from the Swanson River Field and there is an estimated ultimate remaining recovery of 40 to 60 million stock tank barrels of oil.

Gas was discovered in the Swanson River Field on May 18, 1960. All gas wells have been shut-in since 1962. The field has produced more than 12 billion cubic feet (BCF) of dry gas, 1 million barrels of natural gas liquid, and 1,642 BCF of wet gas.

Marathon Oil Company made the initial discovery in the Beaver Creek Field on February 10, 1967. Beaver Creek Unit Well No. 2 was the discovery well. Oil was discovered in the Beaver Creek Field on December 17, 1972, with the Beaver Creek Unit Well No. 4 being the discovery well. As of June 1986, the Beaver Creek Field had produced more than 38 BCF of gas, 1 BCF of wet gas, and 3 million barrels of oil.

Standard Oil Company of California (Chevron USA) discovered the Birch Hill Field on June 14, 1965, with the SOCAL Birch Hill Unit Well No. 22-25 being the discovery well. This single well field produced more than 65 million cubic feet (MMCF) of gas prior to shut-in in 1965.

The Cannery Loop Field was discovered by Union Oil Company of California (UNOCAL) on May 16, 1979. The discovery well was the Cannery Loop Unit No. 1. The field has been shut-in since discovery, but production is scheduled to commence in 1987.

The Falls Creek field was discovered on June 25, 1961, by SOCAL. The Falls Creek Unit No. 1 was the discovery sell. Another single well field, Falls Creek has been shut-in since its discovery.

UNOCAL discovered the Kenai Gas Field on October 11, 1959. The Kenai Unit Well No. 14-6 was the discovery well. Prior to June 1986, the Kenai Gas Field had produced almost 1,700 BCF of natural gas and an additional 12,000 barrels of natural gas liquids. The Sterling, Beluga, and Tyonek Formations produce from multiple horizons. The Kenai Gas Field is a major supplier of natural gas for Anchorage and the surrounding communities

Halbouty Alaska Oil Co., Alaskan Oil and Mineral, and King Oil Inc., discovered the West Fork Field on September 26, 1960. The well produced more than 1.5 BCF of gas prior to being plugged and abandoned in September 1986.

Other Cook Inlet Basin Fields

Granite Point, McArthur River, Middle Ground Shoal, Redoubt Shoal, and Trading Bay are offshore oil fields within Cook Inlet. All are producing fields except Redoubt Shoal which, has been shut-in since discovery.

McArthur River, Middle Ground Shoal, Trading Bay and North Cook Inlet are Cook Inlet gas field that are currently producing gas. North Middle Ground Shoal has been abandoned. Ivan River, Moquaskie, Nicolai Creek, Stump Lake, West Foreland, Albert Kaloa, Beluga, and Lewis River fields are all gas fields on the west side of Cook Inlet. Beluga and Lewis River fields are currently in production. Albert Kaloa Field has been abandoned and the others have been shut-in.

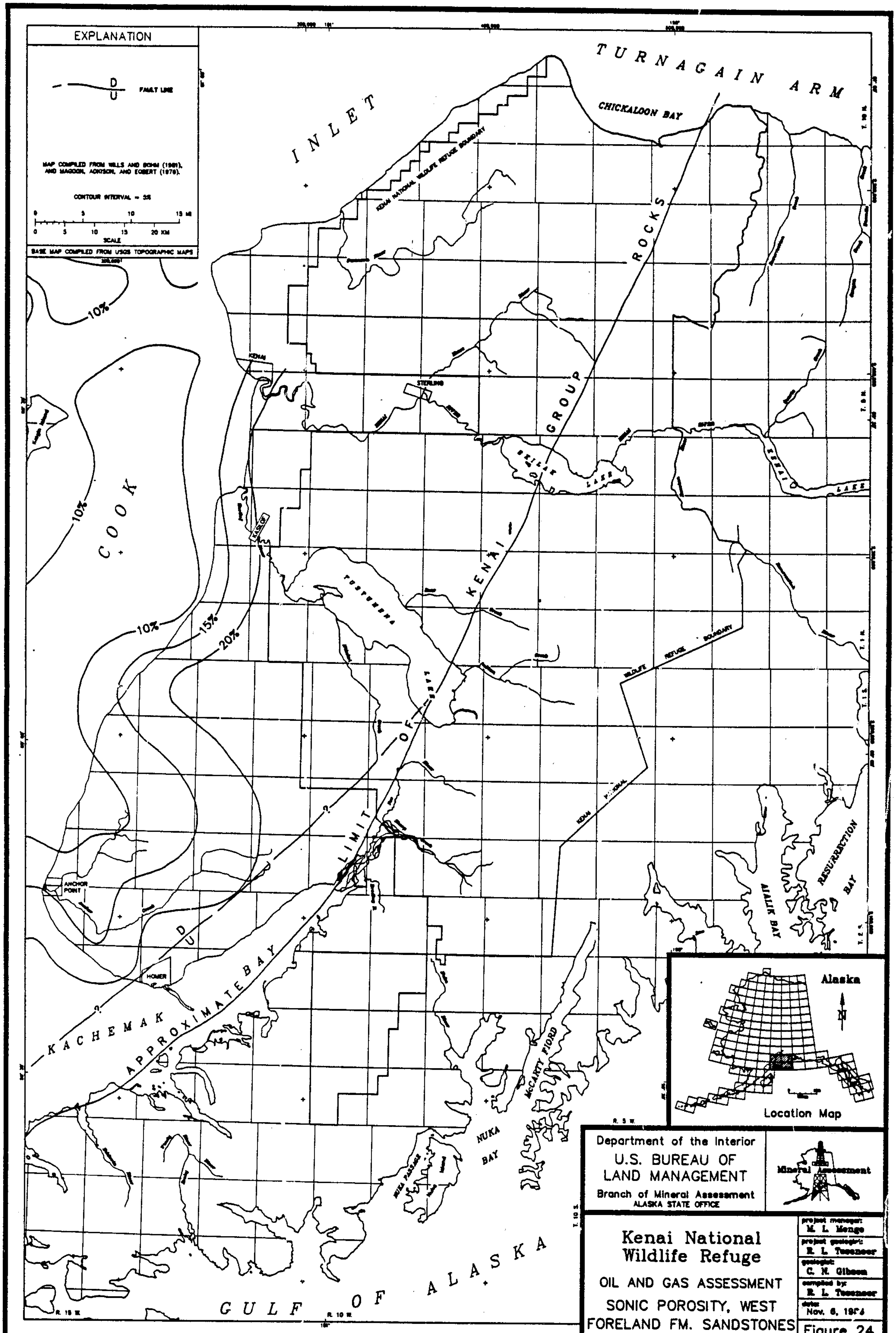
Potential for Oil and Gas Occurrences

Oil and Gas Occurrence Potential

KNWR can be divided into two areas of different potential for hydrocarbon occurrence. One of these areas has a high potential for hydrocarbon occurrence, while the other has a low potential for hydrocarbon occurrence (plate 2). These two areas are divided by the Knik Fault, which juxtaposes two different rock types.

The area with high hydrocarbon occurrence potential has a BLM mineral potential classification for hydrocarbons of H/D (see Appendix C). This area is underlain by the clastic sediments of the Tertiary Kenai Group, and the marine sediments of the Tuxedni Group. All oil and gas production in the Cook Inlet Basin is from the Kenai Group (table 1). Eighty percent of the oil production is from the Hemlock conglomerate, 18 percent is from the Tyonek Formation, and 2 percent is from the West Foreland Formation (Magoon and Claypool, 1981). Gas is produced from the Tyonek, Beluga, and Sterling Formations, with the Sterling Formation being the major gas reservoir in the Cook Inlet Basin. In KNWR, oil is produced from the Hemlock Conglomerate in the Swanson River Field and from the Tyonek Formation in the Beaver Creek Field (this is the only production of oil on the Kenai Peninsula). Gas is produced from the refuge in the Beaver Creek Field, although there are numerous gas field to the west of the refuge.

Figures 7, 9, 11, and 13 show the amount of sandstone (the most likely reservoir rock) that can be expected in the West Foreland, Hemlock, Tyonek, and Beluga Formations within the refuge. Figures 24 through 27 show the sonic porosities that can be expected in these same formations. The percentage of sandstone in the Sterling Formation is probably as great, if not greater, than any of the other four formations. The porosity of the Sterling Formation in seven fields ranges from 26 percent to 36.5 percent (AOGCC, 1985). These figures indicate that all five formations of the Kenai Group have the potential for being excellent reservoir rocks within the refuge.


EXPLANATION
FAULT LINE
MAP COMPILED FROM WILLS AND BOHM (1981), AND MAGOON, ADKISON, AND EGBERT (1976).
CONTOUR INTERVAL = 5%
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
COOK INLET
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
ROCKS
GROUP
KENAI
LIMIT OF
APPROXIMATE BAY
KACHEMAK
KENAI
STERLING
SKILAK LAKE
KENAI LAKE
TUSTUMENA
ANCHOR POINT
HOMER
10%
15%
20%
RESURRECTION BAY
AIALIK BAY
McCARTY FIORD
NUKA BAY
NUKA PASSAGE
GULF OF ALASKA
Alaska
N
Location Map
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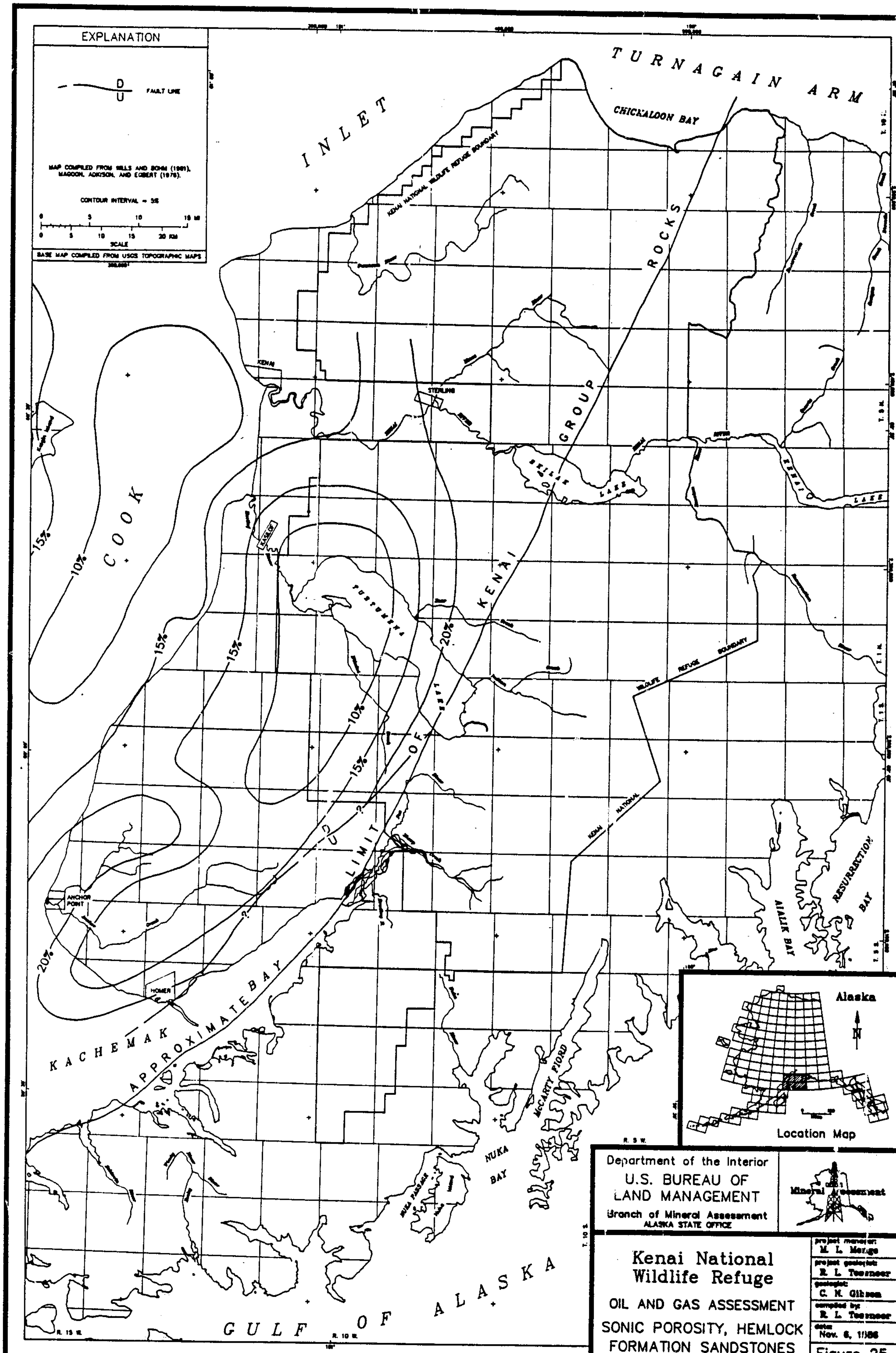
ALASKA STATE OFFICE
Mineral Assessment
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
SONIC POROSITY, WEST FORELAND FM. SANDSTONES
project manager: M. L. Menge
project geologist: R. L. Tesneer
geologist: C. N. Gibson
compiled by: R. L. Tesneer
date: Nov. 6, 1984
Figure 24.



Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE

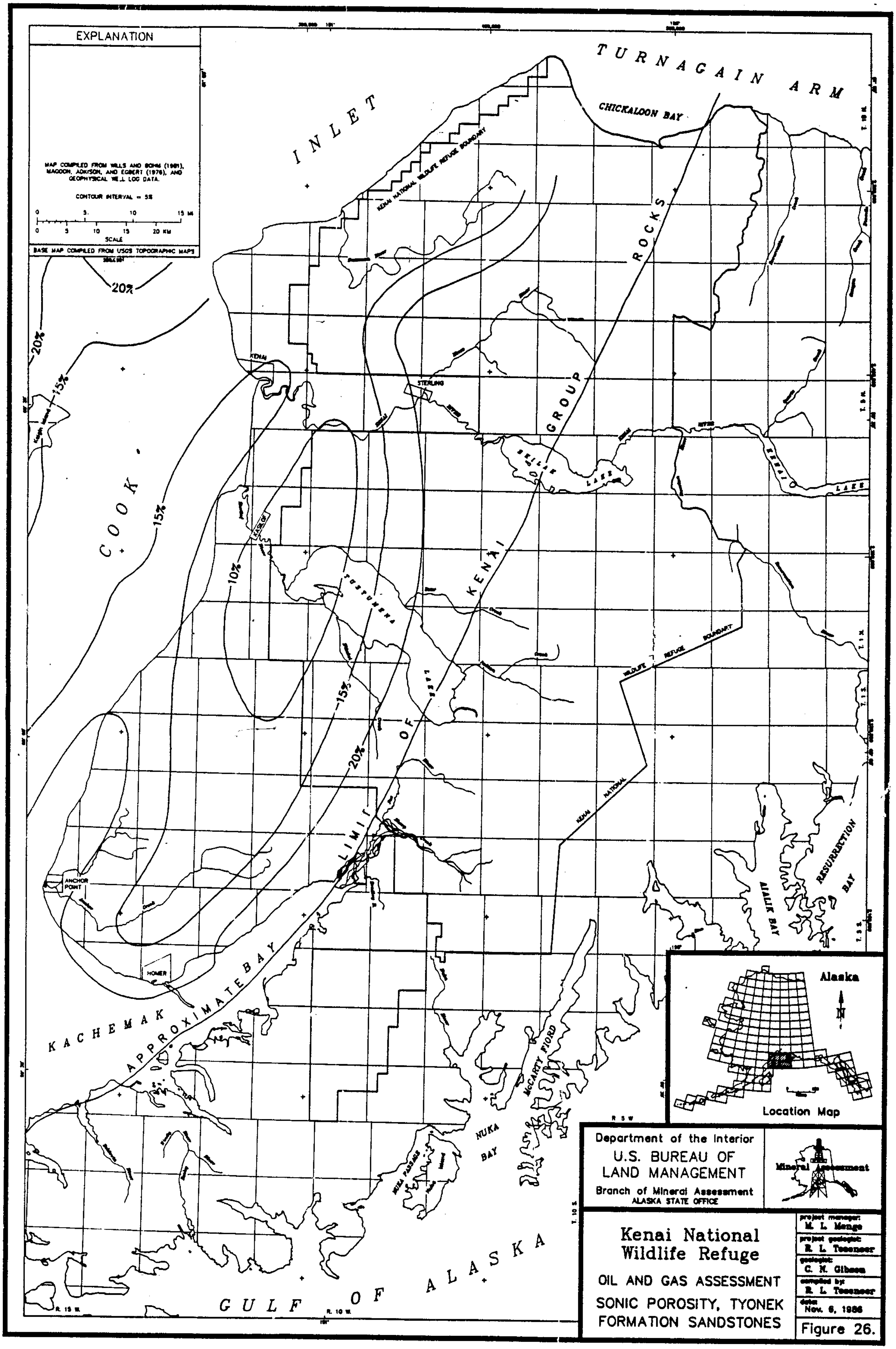
Kenai National Wildlife Refuge

OIL AND GAS ASSESSMENT

SONIC POROSITY, HEMLOCK FORMATION SANDSTONES

project manager: M. L. Menge
project geologist: R. L. Teesmeer
geologist: C. N. Gibson
compiled by: R. L. Teesmeer
date: Nov. 6, 1986

Figure 25.



EXPLANATION
MAP COMPILED FROM WILLS AND BOHM (1981), MAGOON, ADKISON, AND EGBERT (1976), AND GEOPHYSICAL WELL LOG DATA.
CONTOUR INTERVAL = 5%
SCALE
BASE MAP COMPILED FROM USGS TOPOGRAPHIC MAPS
TURNAGAIN ARM
CHICKALOON BAY
INLET
COOK
KENAI NATIONAL WILDLIFE REFUGE BOUNDARY
KENAI
STERLING
SKILAK LAKE
KENAI LAKE
TUSTUMENA
LAKE
LIMIT OF KENAI GROUP ROCKS
20%
15%
10%
ANCHOR POINT
HOMER
KACHEMAK
APPROXIMATE BAY
McCARTY FIORD
NUKA BAY
AIALIK BAY
RESURRECTION BAY
GULF OF ALASKA
Alaska
Location Map
Department of the Interior
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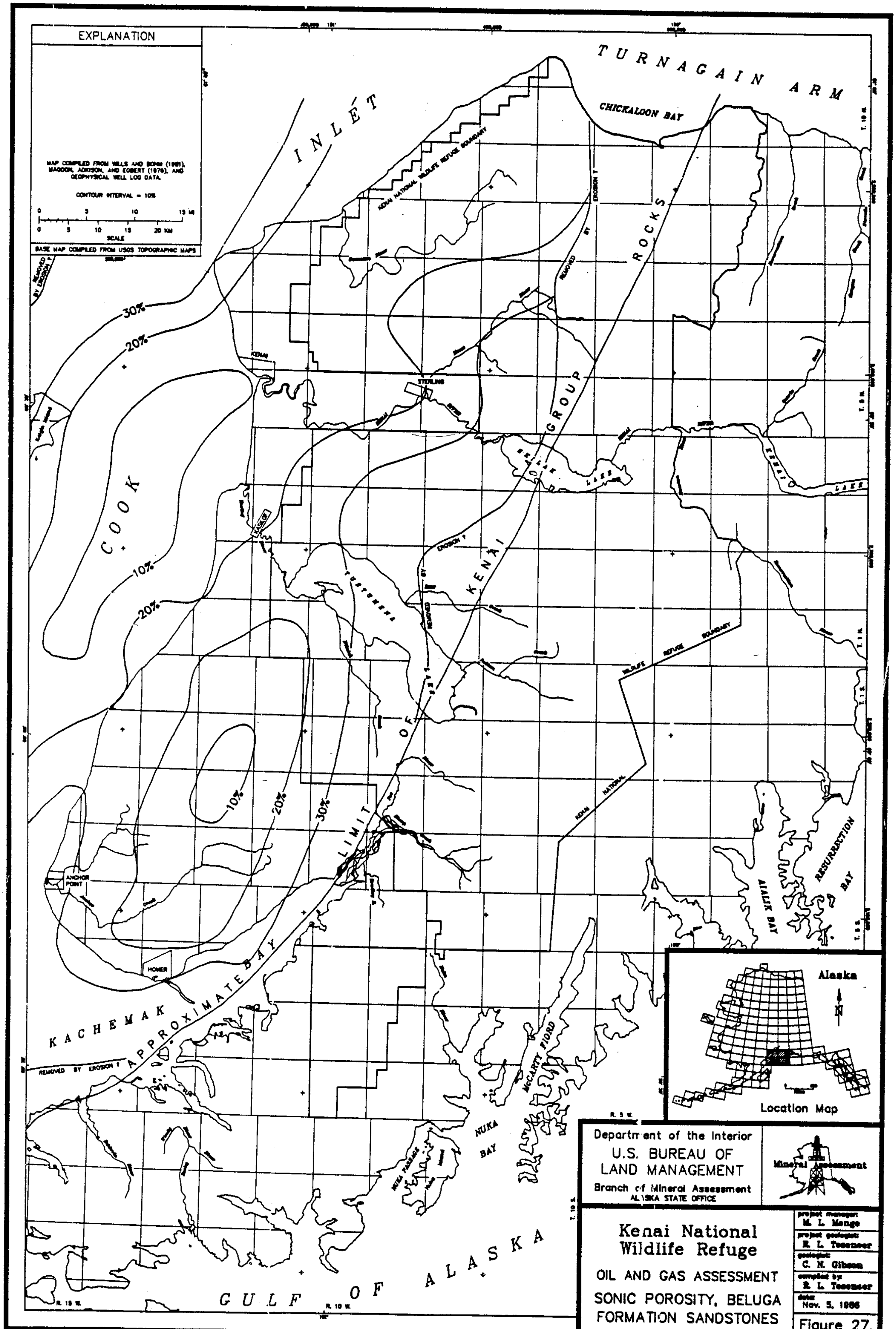
Branch of Mineral Assessment
ALASKA STATE OFFICE
Mineral Assessment
Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
SONIC POROSITY, TYONEK FORMATION SANDSTONES
project manager: M. L. Menge
geologist: C. N. Gibson
date: Nov. 6, 1986
Figure 26.



Kenai National Wildlife Refuge
OIL AND GAS ASSESSMENT
SONIC POROSITY, BELUGA FORMATION SANDSTONES
Figure 27.

The presence of the marine Tuxedni Group rocks under the Kenai Group within the refuge means that the probable source rock for all the Cook Inlet Basins oil is in close proximity to the potential reservoir rocks. At Swanson River Field, the intervening Cretaceous rocks have been removed by erosion.

The area with low hydrocarbon occurrence potential has a BLM mineral potential classification of L/D. This area is underlain by the metamorphosed and complexly deformed rocks of the McHugh Complex and the Valdez Group. Any original porosity in these rocks has probably been destroyed during metamorphism and deformation. Any available porosity for hydrocarbon accumulation is likely to be fracture porosity. Due to the lack of porosity, hence reservoir rocks, and the lack of source rocks, it is extremely unlikely that there would be an accumulation of hydrocarbons in either the McHugh Complex or the Valdez Group. There is a small possibility that an accumulation of hydrocarbons may occur in this area, most likely in a fractured area near the contact with the Kenai Group. The possibility also exists that the McHugh Complex and Valdez Group are underlain by sedimentary rocks that contain hydrocarbons.

Typical Oil and Gas Development Scenario

Any further development, within the KNWR, would have the benefit of using infrastructures previously established for the production of oil and gas. Services of nearby towns and the existing road system will also benefit any future development in this area.

If another economic field is discovered in KNWR, development and production activities would begin on a year-round basis. Proposed plans for the production and transportation facilities are developed during the economic study of the discovery and submitted to local, State, and Federal agencies for approval. After completing the required review process, the plans are either approved or denied pending further information, studies, and/or modifications. Once approved, construction of permanent drilling/production pads, roads, and pipelines could begin. The first construction activities would be to construct a main road between an existing road system and the field, the necessary pads, and the pipelines. Once the main road is completed, production facilities would be transported to the field and assembled. These buildings will be designed to last the life of the field; depending upon the size of the field and the reservoir characteristics, one would expect the field to produce 15 to 30 years.

For illustrative purposes, figure 28 shows the location of the facilities needed to produce a hypothetical prospect. The placement and general design of these facilities is based on the hypothetical shape of the prospect and the assumption that the hydrocarbon reservoir characteristics and surface features are favorable to a maximum directional drilling - minimum surface disturbance condept. It should be understood that actual development could deviate greatly from the presented scenario. Only after the unknown parameters are

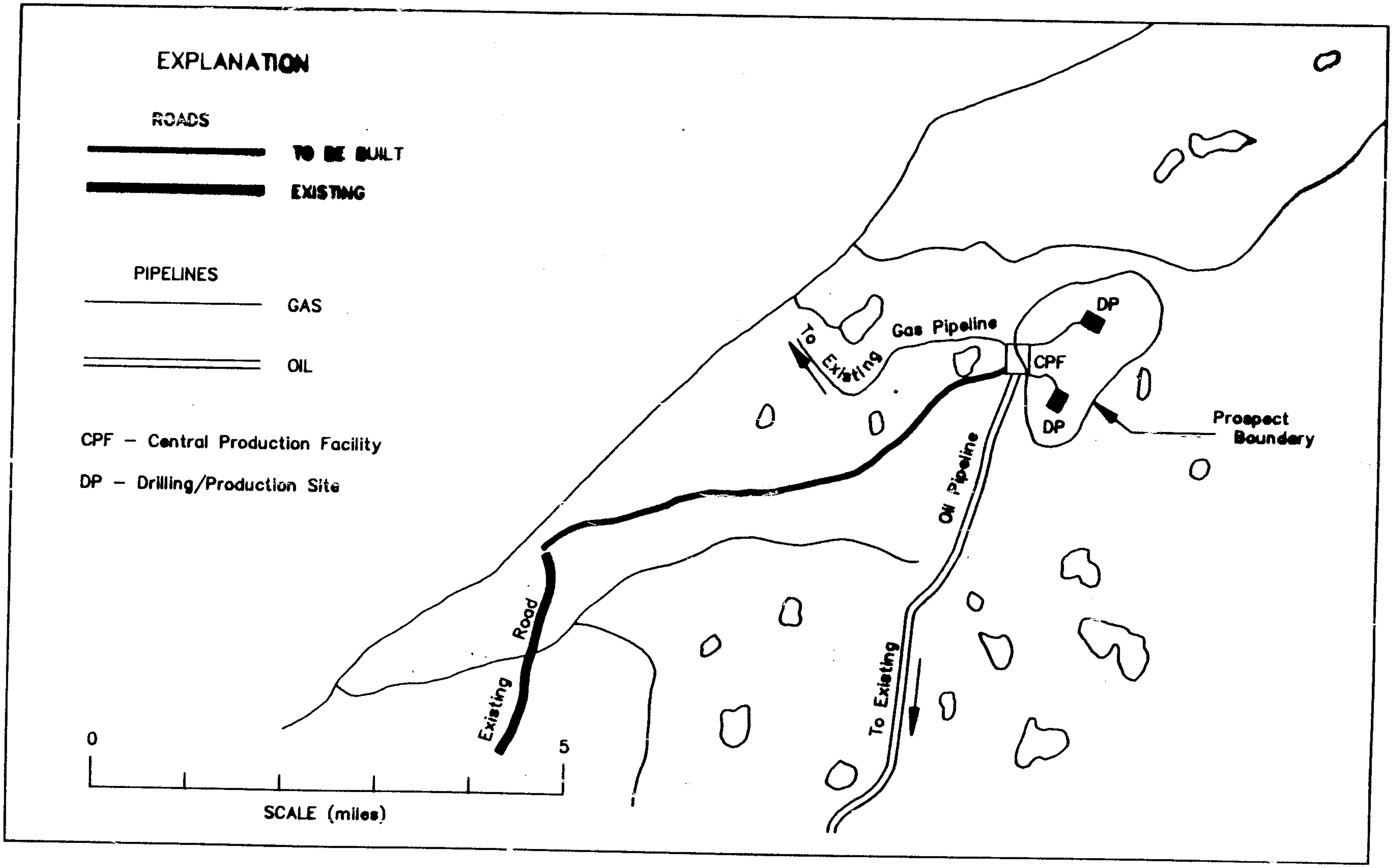


Figure 28. Development scenario for a hypothetical prospect in Kenai National Wildlife Refuge.

TABLE 2

PRODUCTION FACILITIES
FOR THE KNWR HYPOTHETICAL PROSPECT

Facility	Areas Disturbed (each)	Cubic Yards of Gravel to Construct (each)
Central Production Facility Pad	40	130,000
Drilling/Production Pads	15	45,000-50,000
Roads and Parallel Pipelines	5 acres/mile	16,000 yd^3/mile

TABLE 3

TOTAL ACRES DISTURBED AND TOTAL GRAVEL REQUIREMENTS FOR THE DEVELOPMENT OF THE KNWR HYPOTHETICAL PROSPECT

Facility	Acres Disturbed	Cubic Yards of Gravel to Construct
Central Production Facility Facility Pad (1)	40	130,000
Drilling/Production Pads (2)	30	96,000
Roads (8.5 miles)	43	136,000
TOTALS	113	362,000

calculated, can the regulatory agencies work with the operator to minimize surface disturbance while depleting the resources. Table 2 estimates the acreage disturbed and gravel requirements for each facility, and table 3 is a summary of total acres disturbed and gravel required for the hypothetical project. Drilling/production pads shown in the scenario are each designed to produce approximately 2,600 acres. Once the hydrocarbons are depleted from the prospect, the wells would be plugged and abandoned, the facilities would be removed, and the surface would be reclaimed per Federal regulations.

Production Facilities

Facilities needed for the production of oil and gas are the central production facilities, drilling/production pads, pipelines, and roads.

Central Production Facility (CPF)

The CPF is the headquarters and primary operations center for the production activities of the field. Pads needed to support office buildings, compressor plant (if needed), warehouse, and tank settings would be approximately two feet thick and cover approximately 40 acres. Each of these pads would require approximately 130,000 cubic yards of gravel.

Gravel, needed for the construction of the production facilities, could be mined, if available, near the field or hauled from an existing gravel pit.

Office buildings would accommodate 2-10 management and clerical personnel. An additional 10-40 workers would be needed to maintain the operation of the field.

Produced oil would be treated and pumped into tank settings to separate the oil and water. The water is removed and either pumped or trucked to injection wells for disposal, and the oil would be pumped or trucked to the Chevron or Tesoro refineries located north of Kenai, Alaska. Produced gas could either be piped to existing gas lines or reinjected into the subsurface. Production equipment necessary for the operations of the field will depend on the type of production (gas, oil, or both) and the most economical method of oil transportation (trucked or piped).

Drilling/Production Pads

Drilling rigs would be the initial equipment located on the drilling/production pads. As wells are completed, wellheads and pipelines would be put in place. Selected pads may also support additional tank settings for oil storage.

The size of these pads is dependent upon the number of wells they support, distance between the wells, the gathering facility required, and any desired storage which may be needed. In the scenario, two pads are shown to cover 15 acres each. These pads are hypothetically designed to support 20-30 wells based on 80-160-acre spacing. The pads would be approximately two feet thick and would require 45,000-50,000 cubic yards of gravel per pad. Actual field characteristics may require more smaller pads supporting fewer wells.

Water for domestic use could be obtained by drilling water wells, trucking it in, or building a pipeline from a nearby water source. Sewage could be eliminated by a septic tank system, by truck or by pipeline to an existing sewage system. All trash would be transported to an approved disposal site.

Fuel storage would hold diesel and other refined petroleum products necessary for operating the equipment of the CPF. The area would be diked to contain any spills which may occur. Power lines would be built to the field to provide electricity. During electrical outages, a back-up generator would provide emergency power.

Depending upon the proposed depth and subsurface conditions, production wells will take 10-60 days to drill and complete. Production from each well is piped to a tank setting (oil) or treating facility (gas) where it is metered and piped or trucked to the buyer. Unusable drilling mud and cuttings are stored in reserve pits located on the pad. As wells are completed, this material can be buried as the reserve pit is filled in or transported to a disposal site.

Pipelines and Roads

Pipelines will run from each well to a tank setting or treating facility. Depending upon the location of the water disposal wells, produced water could either be piped or trucked. Diameter of the pipe will be three to twelve inches, and all pipelines will most likely be buried. A main pipeline leaving the field will be built along the most direct route to an existing pipeline or refinery. Approximately 2.5 acres/mile would be disturbed while burying the pipeline.

Roads will connect all pads within the field. They will be built with a crown width of 35 feet and will be approximately two feet thick. Each mile of road will cover five acres of surface and require 16,000 cubic yards of gravel. Total road mileage varies between projects, depending on the size and surface features of each prospect.

Economic Potential

The development or economic potential of an area considers not only the geology environment concerning the existence of mineral resources, but also the nongeologic environment as well.

The nongeologic environment includes such considerations as market availability, the existing infrastructure in the subject area, price projections, costs of production and marketing, anticipated rate of return, and also alternative investment opportunities.

Current petroleum price projections compiled from a variety of sources (U.S. Department of Energy, 1985; Data Resources Inc., 1986; Chevron Corp., 1986) are significantly lower than previous forecasts completed earlier in the 1980s (Appendix D, table 1). The range of oil prices projected in these current forecasts vary from $18 to $42 per barrel by the year 2000 (constant 1984/85 dollars). With such a wide spread in forecasts, it is difficult to assess future impacts of this variable on future exploration activities. It was of interest to note that both a private research firm and a major oil company forecast a crude oil price of $35/barrel, whereas the most optimistic level of $42/barrel was a forecast of the U.S. Department of Energy (DOE) and was dependent on high economic growth. Assuming that high economic growth is not achieved, the DOE mid-range forecast of $36.75 is less than $2/barrel higher than those of the private sector. This level ($36.75/barrel by the year 2000) is approximately $5/barrel or 12 percent less than the average annual refiners' cost of imported crude in 1981/82 (constant 1984 dollars). This scenario does reflect an optimistic picture as compared to the current pricing structure and would be expected to provide incentives for future exploration/production of the Kenai Refuge.

Other forecasts from the same sources indicate an upward trend in petroleum demand, but conversely project a decline in domestic production which is indicative of a decrease in domestic exploration activities.

One last petroleum price projection that should be considered is the scenario presented by Arlon Tussing (Bayless, 1987; Reinwand, 1987), a Seattle based energy economist. Mr. Tussing, in late 1980, against all conventional price projections, correctly forecast that international oil prices would soon collapse. In January 1984, prior to the concern of most energy forecasters, he stated that we were headed for a 10-year cycle of falling prices, and he projected that oil would soon drop within the range of $12 to $20 per barrel. To date, this forecast has been quite accurate.

Mr. Tussing's latest forecast is even more foreboding, as he expects oil prices in constant dollars to remain within a range of $10 to $20 a barrel through the rest of the century. Beyond this timeframe, he expects energy prices to decline even further.

The basis for this scenario is "fuel switching." Mr. Tussing states that "many" of the industrial users are now equipped to use alternate fuels such as oil, gas, or coal, depending on the prevailing price. He points out that the exceptional high prices during the six-year period between 1979 and 1985 were possible only because heavy industrial users were not at that time equipped to switch fuels and were heavily dependent on oil as a bulk fuel. This stemmed from the fact that exceptionally low oil prices prevailed in the 1950s and 1960s and this trend was expected to continue ad-infinitum. He further points out that for a century, between 1878 and 1978, crude oil prices never exceeded $15/barrel in 1986 dollars and the average wellhead price during this 100-year period was between $8 and $9 a barrel. Mr. Tussing believes that as long as technological progress is self-sustaining, the long-term price trend for oil can only be downward.

The wide divergence in oil price projections just presented are indicative of the future uncertainty which exists in the national petroleum industry. As we have seen, though, most mainline economists are forecasting an upward trend in long-term oil prices. Although this is considered a promising sign for the industry as a whole, this is foreshadowed by forecasts of a long-term decline in U.S. production. This decline was brought on by a general cutback in drilling and production activities by U.S. petroleum companies, triggered by an excess world oil supply and resultant low product prices. Future expansionary efforts by the petroleum industry would be anticipated to take place in areas where, hopefully, capitol costs can be held down or, in lieu of this, in areas of a great promise.

The Kenai National Wildlife Refuge appears to be an area where capitol costs can be held down. Good road access is presently available to the Swanson River and Beaver Creek Fields, and any further development in these areas would have the benefit of a previously established infrastructure for the production of oil and gas. Services of nearby towns would also benefit any future development in the area. In contrast to the above, it should be noted that approximately one-half of the area which has been determined to be "high potential" is presently within a wilderness area. Roads have not been built through most of this wilderness area and access is limited to trails, canoe, float plane, etc.

To determine how much of the area with high hydrocarbon occurrence potential would be within the high development potential area, an economic analysis of a "typical" prospect was performed to determine how many miles of pipeline could be built to carry oil from the prospect to the refineries near Kenai, Alaska. Using the parameters shown in table 4, it was determined that this "typical" prospect could support a 50-mile pipeline and still provide investors with a 14 percent return on their investment. A circle with a 50-mile radius was drawn around the refineries, and it took in all of the high hydrocarbon occurrence potential area, with the exception of the extreme northeastern corner. As there is an existing road (along the Kenai to Anchorage pipeline) to that corner, the per-mile cost of building an oil pipeline to the corner would be cut enough to allow the construction of the three or four miles of extra pipeline required to reach the corner.

Based on the above facts and assumptions, as well as the existence of a promising geologic potential (rated as "high"), the developmental potential for this corresponding area is also rated as "high." This means that there is a high probability that further oil and gas exploration and development activities will take place within the refuge area boundaries within the next 15 years (plate 3). Constraints to this expected development would be an unfavorable supply and demand picture and/or poor market prices. The area rated as having a "low" geologic potential was similarly rated as having a low development potential.

Overview

In 1985, Alaska contributed nearly 20 percent of domestic petroleum production (United States Department of Energy, Energy Information Administration 1986). In comparison, Alaska is a relatively minor producer of natural gas, with marketed production of approximately 300 billion cubic feet per year in 1985 (United States Department of Energy, Energy Information Administration 1986a). However, Alaska is an exporter of natural gas in the form of liquified natural gas (LNG), which is primarily shipped to Japan.

Fundamental changes in the petroleum industry since the early 1970s will certainly be a force in shaping the industry's future. This period brought two major crude oil price shocks; rapid expansion in petroleum demand and heavy reliance on foreign sources of supply to meet domestic needs. Similarly, the consumer experienced shortages in natural gas supply which resulted in a new era of gas price regulation (see Appendix D for a detailed discussion of these changes). The rapid growth of the energy sector in the late 1970s and early 1980s resulted in the highest petroleum prices ever experienced by the industry. This set the stage for a period of energy conservation efforts followed by declining demand and excess world productive capacity with falling petroleum prices. By the middle of 1986, crude oil prices had dropped to levels at or below prices received in 1973, before the Arab oil embargo. Natural gas price increases stimulated drilling and production in the early 1980s, which has resulted in domestic surplus capacity (gas bubble) and depressed prices. The present unstable nature of the oil and gas industry has resulted in a great deal of restructuring within the industry and expectations for the future are very uncertain.

Most recent long-term price forecasts project an upward trend that will be realized in the 1990s and possibly beyond (see Appendix D for specific prices and trends). Domestic petroleum demand is expected to rise slightly above the 1985 level of 15.7 million barrels per day to a range from 15.9 to 18.1 million barrels per day by the year 2000. Natural gas demand could also increase from 17.4 trillion cubic feet per year in 1985 to a possible range from 17.1 to 20.4 trillion cubic feet per year in the year 2000. In contrast, domestic production of petroleum and natural gas is projected to decline below 1985 levels by the year 2000 (see Appendix D for a more detailed discussion of historic and future petroleum and natural gas demand and supply relationships).

Therefore, the United States' dependency on foreign sources of hydrocarbon supplies is expected to increase above current levels. Based on

TABLE 4

Assumptions Used for the "Typical" Prospect Analysis

Size of prospect	5,200 acres
Net pay	22 feet
Volume of prospect	114,400 acre-feet
Porosity*	21 percent
Permeability*	55 millidarcies
Formation volume factor*	1.23
Water saturation*	40 percent
Recovery factor**	35 percent
Oil price	$18.00 barrel (held constant throughout life of field)
Recoverable reserves	32,000,000 stock tank barrels
Gross income	$576,000,000
Initial investment costs:	
Exploratory wells (4)	$7,000,000 each
Development wells (28)	$5,000,000 each
Pads and surface facilities	$10,000,000
Pipeline and road (50 miles)	$500,000/mile
Total investment costs	$203,000,000
Annual costs:	
Field life	34 years, with peak production obtained 4 years after discovery and assumed 12.5 percent/year decline thereafter
Operations	$1,000,000/year
Royalties	$3,600,000/year (12.5 percent)
Taxes	$10,406,000/year (43 percent of net profits)
Total annual cost	$15,006,000/year

* - Based on Swanson River Field - Hemlock Zone.
** - Estimated; Swanson River Field, Hemlock Zone is greater than 50 percent.

these projections, there is a considerable gap between domestic consumption and production that can only be filled nationally be exploring new areas and developing any commercial discoveries that are made.

In summary, if the Kenai National Wildlife Refuge was opened to oil and gas exploration and development, some small-scale economic benefits would be expected to the State and the nation. These benefits would, of course, be dependent upon locating commercial quantities of oil and gas and could be further quantified by the size of the discoveries made. Industry has expressed only a moderate interest in further exploration activities in the Kenai Refuge, and this interest is not expected to improve substantially due to current low prices.

A recent announcement, though, has indicated that UNOCAL Corporation, Marathon Oil, and Cook Inlet Region, Inc., are planning to spend over 20 million dollars during the summer of 1987 to put the Cannery Loop Gas Field back into production. The Cannery Loop Gas Field is located near the town of Kenai, just west of the refuge boundary. This is one encouraging sign for the area.

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Appendix A

MEMORANDUM OF UNDERSTANDING
BETWEEN THE
FISH AND WILDLIFE SERVICE
AND THE
BUREAU OF LAND MANAGEMENT
U.S. DEPARTMENT OF THE INTERIOR

BACKGROUND:

Section 1008 of the Alaska National Interest Lands Conservation Act (ANILCA) requires the Secretary of the Interior to initiate an oil and gas leasing program on the federal lands of Alaska; it exempts, "...those units of the National Wildlife Refuge System where the Secretary determines, after having considered the national interest in producing oil and gas would be incompatible with the purpose for which such unit was established." Section 1008 also mandates that:

> "In such areas as the Secretary deems favorable for the discovery of oil or gas, he shall conduct a study, or studies, or collect and analyze information obtained by permittees authorized to conduct studies under this section, of the oil and gas potential of such lands and those environmental characteristics and wildlife resources which would be affected by the exploration for and development of such oil and gas."

Section 304(g) of ANILCA requires that the Secretary of the Interior prepare a "comprehensive conservation plan" for each of the 16 National Wildlife Refuges in the State of Alaska. Among other things, these plans are to, "...specify the uses within each such area which may be compatible with the major purposes of the refuge." The U.S. Fish and Wildlife Service (FWS) has the responsibility for preparing the refuge comprehensive conservation plans and is using the refuge planning process to define those areas on refuges where oil and gas exploration and development may be compatible with the purposes for which each refuge was established.

PURPOSE:

To fully comply with Section 1008 of ANILCA (i.e., to consider the national interest in producing oil and gas from refuge lands) an accurate defensible oil and gas resource assessment should be prepared for each National Wildlife Refuge in Alaska. The FWS has limited technical expertise in assessing mineral potentials. However, this expertise does exists within the U.S. Bureau of Land Management (BLM). The purpose of this memorandum is to establish cooperative procedures between the FWS and the BLM for the mutual responsibility of assessing the oil and gas potential of National Wildlife Refuge lands in Alaska.

IT IS MUTUALLY AGREED THAT:

The BLM will develop an oil and gas resource assessment for each of the 16 National Wildlife Refuges in the State of Alaska. These assessments will consist of the following items (to the extent that available data permits):

1. A detailed narrative discussion of the geologic character of the refuge.

2. A map showing all known geologic formations and geologic features pertinent to the mineral assessment.

3. A geologic cross section showing the sub-surface character of the study area.

4. A detailed discussion of the engineering aspects, if there is a potential for development in the area, including the types of facilities and the infrastructure necessary to economically develop the hydrocarbon potential.

5. A generic development scenario map that will graphically portray the facilities and infrastructure discussed in item 4 above.

6. An economic assessment that will include:

   a. a brief overview of the national energy situation and discussion of the importance of Alaskan oil and gas production.
   b. a generalized discussion of the economic potential for oil and gas production from the refuge being evaluated.
   c. a discussion of the factors that may affect future oil and gas development on the refuge.

The above six items shall be considered the minimum elements to be included in any refuge assessment. If sufficient non-proprietary geological and geophysical data exist, and the hydrocarbon resources warrant further description, some or all of the following items (time permitting) will also be included in the resource assessment:

a. structural contour maps showing the location and surface areas of potential mineral occurrences,
b. maps showing the magnetic and/or gravity character of the area,
c. maps showing the thickness of identified rock formations,
d. reservoir character map showing the porosity, water saturation, and permeability characteristics of potential reservoirs, and
e. a detailed development scenario map showing roads, docks, pipeline corridors, etc. required to develop the prospects.

In preparing the oil and gas resource assessments the BLM shall make use of 1) existing literature, 2) geological and geophysical information and data collected from FWS lands by industry permittees (see Memorandum of Understanding between FWS and BLM dated August 1984—attachment 1), and 3) geological and geophysical information and data collected on or adjacent to FWS lands by the BLM, the U.S. Geological Survey, the State of Alaska, and other governmental agencies. During the evaluation process, BLM geologists will make official contacts with mineral companies that may have an interest in the area. These companies will be given an opportunity to submit data for consideration and they will also be given the opportunity to discuss their feelings on the study area and its oil and gas development potential with the evaluating geologists. All interactions will be documented and submitted to the Fish and Wildlife Service at the close of the project.

The oil and gas resource assessments prepared by BLM will be delivered to the FWS in a form suitable for public release. These assessments will be public documents, and the FWS will make copies of the assessments available for public review. All formal communications with the public concerning the management of FWS lands (e.g., the opening of refuge lands to oil and gas exploration or development) will be the responsibility of the FWS.

In developing the oil and gas assessments, proprietary information that was obtained by the BLM will be shared with the FWS as support for statements made in the assessment; however, proprietary information will not be included in the public report.

The number of refuge resource assessments that BLM will complete each year and the amount of funding that the FWS will provide to BLM will be determined on an annual basis by mutual agreement. The following three goals have been established to assist the FWS and the BLM in planning their work commitment for completing the refuge oil and gas assessments:

1. The Becharof, Alaska Peninsula, Yukon Flats and Kenai National Wildlife Refuge oil and gas assessments will be completed during the 1986 Fiscal Year.

2. If at all possible, the oil and gas assessments for the remaining 12 refuges will be completed during the 1987 and 1988 Fiscal Years.

3. The FWS will reimburse the BLM for completion of oil and gas assessments and FWS will prioritize the assessments to be completed each year, with consideration for concurrently conducting analyses, if possible, on refuges in similar geographic locations or of similar geologic character.

However, nothing in this MOU shall be construed as requiring either agency to assume or expend any funds in excess of appropriations available. The remaining 12 National Wildlife Refuge (NWR) resource assessments will be conducted in the priority order established by the FWS on an annual basis:

1. Togiak NWR
2. Tetlin NWR
3. Kanuti NWR
4. Yukon Delta NWR
5. Koyukuk NWR
6. Nowitna NWR
7. Innoko NWR
8. Selawik NWR
9. Kodiak NWR
10. Alaska Maritime NWR
11. Izembek NWR
12. Arctic NWR

Amendments to this agreement may be proposed by either party and shall become effective upon mutual approval. Meetings to discuss the MOU may be called by the FWS Regional Director or the BLM State Director.

Regional Director
U.S. Fish and Wildlife Service

MAR 17 1986
Date

State Director
Bureau of Land Management

2-26-86
Date

Attachment I

MEMORANDUM OF UNDERSTANDING
BETWEEN THE
FISH AND WILDLIFE SERVICE
AND THE
BUREAU OF LAND MANAGEMENT
U.S. DEPARTMENT OF THE INTERIOR

ARTICLE 1 Background and objectives

Jointly the Fish and Wildlife Service (FWS) and the Bureau of Land Management (BLM) share responsibility to help meet Department of the Interior objectives in Section 1008 of the Alaska National Interest Lands Conservation Act (ANILCA) of December 1980. The FWS is authorized to issue permits for the study of oil and gas on national wildlife refuges; the BLM may analyze resulting data for identification of potential.

The FWS is issuing permits for surface geology study on all refuges. Permits for geophysical exploration may be issued on refuges having approved Comprehensive Conservation Plans. Data from both activities are required to be furnished to the FWS.

This Memorandum of Understanding is entered into to initiate the role of BLM to accept such data from FWS and be responsible for its confidentiality.

ARTICLE 2 Statement of work

The FWS agrees to deliver to BLM data collected from permittees of oil and gas studies provided for in Section 1008 of ANILCA. The BLM agrees to accept the data, store it, and keep it confidential.

ARTICLE 3 Term and modification

This understanding shall continue from date of signature ten years hence. It may be modified and/or extended by mutual agreement, and terminated by either party with sixty days notice.

Robert E. Putz
Regional Director
Fish and Wildlife Service

8/2/84
Date

Michael J. Penfold
State Director
Bureau of Land Management

8-27-84
Date

APPENDIX B

Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Texaco, Pt. Possession Unit	Sec. 22, T 10 N, R 07 W	15,296'	12/23/66	04/02/67	D&A
Texaco (?), Swanson Lakes No. 1	Sec. 01, T 09 N, R 07 W	12,256'	01/03/68	03/21/68	D&A
ARCO, Funny River No. 1	Sec. 02, T 04 N, R 09 W	18,009'	11/26/83	03/05/84	D&A
Forest Oil, Sunrise Lake Unit	Sec. 15, T 08 N, R 08 W	14,500'	02/02/70	04/16/70	D&A
Socal, Swan Lake Unit	Sec. 27, T 08 N, R 07 W	11,984'	08/06/61	09/21/61	D&A
ARCO/CIRI, Wolf Lake State No. 1	Sec. 29, T 07 N, R 09 W	14,024'	11/12/83	02/25/84	D&A
Halbouty, Bishop Creek Unit	Sec. 11, T 07 N, R 11 W	9,034'	08/20/60	09/10/60	D&A
Socal, Mink Creek Unit No. 14-20	Sec. 20, T 07 N, R 09 W	12,395'	01/31/70	03/25/70	D&A
Socal, Naptowne Unit No. 24-8	Sec. 08, T 06 N, R 08 W	15,226'	01/09/66	04/13/66	D&A
Socal, West Fork No. 233-16	Sec. 16, T 06 N, R 09 W	9,150'	03/29/62	04/24/62	D&A
Socal, Soldotna Creek No. 22-32	Sec. 32, T 07 N, R 09 W	14,550'	04/29/62	09/21/62	D&A
No. 22A-32 (34)	Redrill	14,796'	12/13/62	12/22/67	D&A
ARCO/CIRI, Wolf Lake State No. 2	Sec. 29, T 07 N, R 09 W	14,451'	11/10/84	02/23/85	D&A
Union, Sterling Unit No. 43-28	Sec. 28, T 06 N, R 09 W	5,634'	06/26/62	07/06/62	D&A
Union, Kenai Unit No. 41-2	Sec. 02, T 05 N, R 11 W	5,735'	09/14/66	09/25/66	D&A
Union, Kenai Unit No. 13-8	Sec. 08, T 05 N, R 11 W	5,506'	11/22/64	12/07/64	D&A
Trinity Canadian, Homesteaders No. 1	Sec. 15, T 05 N, R 09 W	13,890'	04/10/66	07/13/66	Sus
Union, COHOE No. U-1	Sec. 08, T 03 N, R 11 W	15,683'	08/12/73	10/11/73	D&A
Mesa Petroleum, Kasilof No. 2	Sec. 19, T 03 N, R 12 W	8,000'	10/04/68	10/15/68	D&A
Socal, Cape Kasilf	(BH) Sec. 26, T 03 N, R 03 W	14,015'	09/10/74	01/06/75	D&A
Union, Kasilof Unit No. 1	Sec. 30, T 03 N, R 12 W	5,500'	09/26/67	10/05/67	D&A
Union, Clam Gulch Unit No. 1	Sec. 28, T 02 N, R 12 W	14,200'	05/27/78	-------	D&A
Marathon, Clam Gulch Unit No. 1	Sec. 03, T 01 N, R 13 W	15,011'	09/14/68	-------	D&A
Brinkerhoff, Ninilchik River No. 1	Sec. 21, T 01 S, R 13 W	13,082'	12/31/73	-------	D&A

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name		Location*	TD	Drilled	Completed	Status**
Mobil, Ninilchik No. 1		Sec. 24, T 01 S, R 14 W	12,724'	03/22/64	05/18/64	D&A
Pan Am, USA Edna Mae Walker No. 1		Sec. 35, T 01 S, R 12 W	16,300'	11/25/65	03/28/65	D&A
Socal, Deep Creek Unit No. 1		Sec. 15, T 02 S, R 13 W	14,221'	03/19/58	08/06/58	D&A
Superior, Happy Valley No. 31-22		Sec. 22, T 02 S, R 13 W	13,550'	09/09/63	12/02/63	D&A
Pennzoil, Starichkof St. Unit No. 1		Sec. 22, T 03 S, R 15 W	8,775'	08/05/67	--------	D&A
Pennzoil, Starichkof St. Unit No. 1		Sec. 33, T 03 S, R 15 W	12,112'	01/12/67	03/03/67	Sus
Socal, North Fork Unit No. 11-4		Sec. 04, T 04 S, R 13 W	12,462'	01/27/70	03/18/70	D&A
Gulf Oil, Caribou Hills Unit (St.) No. 1		Sec. 24, T 04 S, R 12 W	10,091'	02/26/70	--------	D&A
Socal, Anchor River No. 1		Sec. 29, T 04 S, R 11 W	6,896'	11/26/61	12/19/61	D&A
Socal, Anchor Point No. 1		Sec. 10, T 05 S, R 15 W	14,705'	06/07/62	11/06/62	D&A
Occidental, So. Diamond Gulch No. 1		Sec. 06, T 06 S, R 14 W	10,568'	07/12/62	--------	D&A
Texaco, Coal Bay St. No. 1		Sec. 08, T 06 S, R 12 W	4,013'	11/17/66	11/26/66	D&A
Halbouty, Fritz Creek No. 1		Sec. 04, T 06 S, R 12 W	3,793'	02/17/63	03/03/63	D&A
Marathon, Beaver Creek No. 1		Sec. 34, T 07 N, R 10 W	9,134'	01/04/67	02/09/67	D&A
Marathon, Beaver Creek No. 1-A	(BH)	Sec. 34, T 07 N, R 10 W	10,296'	03/13/67	06/13/67	PGW
Marathon, Beaver Creek No. 2		Sec. 03, T 06 N, R 10 W	15,697'	07/13/67	11/09/67	PGW
Marathon, Beaver Creek No. 3	(BH)	Sec. 27, T 07 N, R 10 W	------	07/26/68	08/10/68	GSI
Marathon, Beaver Creek No. 4	(BH)	Sec. 34, T 07 N, R 10 W	------	06/12/72	11/26/72	POW
Marathon, Beaver Creek No. 5	(BH)	Sec. 27, T 07 N, R 10 W	------	06/10/74	11/21/74	POW
Marathon, Beaver Creek No. 5 (rd)	(BH)	Sec. 27, T 07 N, R 10 W	------	11/01/75	01/17/76	POW
Marathon, Beaver Creek No. 6		Sec. 34, T 07 N, R 10 W	------	11/19/81	04/15/82	PGW
Marathon, Beaver Creek No. 7		Sec. 04, T 06 N, R 10 W	------	03/30/76	07/20/76	GSI
Marathon, Beaver Creek No. 8		Sec. 22, T 07 N, R 10 W	------	08/18/77	12/13/77	D&A
Socal, Birch Hill BH 22-25(1)		Sec. 25, T 09 N, R 09 W	15,500'	11/30/65	05/15/65	GSI
Unocal, Sterling No. 23-15(1)		Sec. 15, T 05 N, R 10 W	14,832'	05/05/61	07/10/61	GSI
Unocal, Sterling No. 43-9		Sec. 09, T 05 N, R 10 W	6,202'	06/19/63	06/29/63	PGW
Unocal, Sterling No. 43-28(2)		Sec. 28, T 06 N, R 09 W	5,634'	06/26/62	07/06/62	D&A
Union, Kenai No. KDU 1(16)		Sec. 06, T 04 N, R 11 W	9,895'	09/13/67	11/02/67	PGW

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Union, Kenai No. KDU 2 (21-8)(17)	Sec. 08, T 04 N, R 11 W	10,522'	07/03/68	08/07/68	PGW
Union, Kenai No. KDU 4 (13-7)(20)	Sec. 07, T 04 N, R 11 W	10,810'	02/11/69	06/07/69	PGW
Union, Kenai No. KDU 5	(BH) Sec. 06, T 04 N, R 11 W	------	08/29/78	09/22/78	PGW
Union, Kenai No. KDU 5 (31-6)	Sec. 31, T 05 N, R 11 W	------	08/29/78	09/22/78	PGW
Union, Kenai No. KDU 6	(BH) Sec. 32, T 05 N, R 11 W	------	12/10/78	01/14/79	PGW
Union, Kenai No. KU 11-6 (13)	Sec. 06, T 04 N, R 11 W	4,459'	06/17/65	06/24/65	PGW
Union, Kenai No. KU 11-8	(BH) Sec. 08, T 04 N, R 11 W	------	08/13/82	08/20/82	PGW
Union, Kenai No. KBU 12X-8	Sec. 07, T 04 N, R 11 W	------	--------	--------	PGW
Union, Kenai No. KU 13-6	Sec. 06, T 04 N, R 11 W	------	06/09/82	06/17/82	PGW
Union, Kenai No. KBU 13-8	Sec. 08, T 04 N, R 11 W	------	07/19/77	08/07/77	PGW
Union, Kenai No. KU 13-8(8)	Sec. 08, T 05 N, R 11 W	5,506'	11/22/64	12/07/64	D&A
Union, Kenai No KU 14-4 (4)	Sec. 04, T 04 N, R 11 W	5,125'	10/18/60	10/30/60	PGW
Union, Kenai No. KU 14-6 (1)	Sec. 06, T 04 N, R 11 W	15,047'	05/28/59	09/26/59	PGW
Union, Kenai No. KU 14X-6	Sec. 06, T 04 N, R 12 W	------	09/22/81	10/27/81	PGW
Union, Kenai No. KU 14-32	(BH) Sec. 32, T 05 N, R 11 W	------	02/16/82	02/26/82	PGW
Union, Kenai No. KU 21-5 (22)	Sec. 05, T 04 N, R 11 W	------	06/29/69	09/22/69	PGW
Union, Kenai No. 21-6	Sec. 06, T 04 N, R 11 W	------	05/06/65	05/17/65	PGW
Union, Kenai No. 21-7 (12)	Sec. 07, T 04 N, R 11 W	4,453'	05/27/65	06/11/65	PGW
Union, Kenai No. 21X-32 (23)	Sec. 32, T 05 N, R 11 W	------	11/05/69	11/25/69	PGW
Union, Kenai No. KU 24-7	(BH) Sec. 07, T 04 N, R 11 W	------	05/12/82	05/22/82	PGW
Union, Kenai No. KBU 31-7	(BH) Sec. 07, T 04 N, R 11 W	------	12/15/81	12/30/81	PGW
Union, Kenai No. 33-1 (17)	Sec. 01, T 04 N, R 12 W	5,136'	01/28/64	02/19/64	PGW
Union, Kenai No. 33-7	Sec. 18, T 04 N, R 11 W	------	--------	--------	---
Union, Kenai No. 33-30 (3)	Sec. 30 T 05 N, R 11 W	5,011'	11/28/59	12/04/59	PGW
Union, Kenai No. 33-32 (10)	Sec. 32, T 05 N, R 11 W	5,232'	05/01/65	05/13/65	PGW
Union, Kenai No. KU 34-31 (2)	Sec. 31, T 05 N, R 11 W	5,809'	10/28/59	11/07/59	PGW
Union, Kenai No. 34-32	(BH) Sec. 06, T 05 N, R 11 W	------	11/23/81	12/07/81	PGW
Union, Kenai No. KU 41-2 (15)	Sec. 02, T 05 N, R 11 W	5,735'	09/14/66	09/25/66	D&A

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Union, Kenai No. KBU 41-7	Sec. 07 T 04 N, R 11 W	------	11/22/79	12/12/79	PGW
Union, Kenai No. KU 41-18	(BH) Sec. 08, T 04 N, R 11 W	14,721'	04/13/71	09/16/71	PGW
Union, Kenai No. KU 41-19 (5)	Sec. 19, T 04 N, R 11 W	5,653'	12/23/60	01/07/61	PGW
Union, Kenai No. KTU 42X-6	Sec. 06, T 05 N, R 13 W	------	--------	--------	---
Union, Kenai No. KU 42-30	Sec. 30, T 05 N, R 11 W	------	08/21/81	10/08/81	PGW
Union, Kenai No. KU 43-6 (11)	Sec. 06, T 04 N, R 11 W	5,706'	05/26/65	06/08/65	PGW
Union, Kenai No. KU 43-6A (18)	Sec. 06, T 04 N, R 11 W	5,300'	08/25/68	09/02/68	PGW
Union, Kenai No. 43-6X	(BH) Sec. 06, T 04 N, R 11 W	------	07/05/79	07/19/79	PGW
Union, Kenai No. KU 47-7	Sec. 07, T 04 N, R 11 W	5,707'	06/15/65	06/25/65	PGW
Union, Kenai No. KU 43-12 (21)	Sec. 12, T 04 N, R 12 W	------	09/29/69	10/12/69	PGW
Union, Kenai No. KU 44-18 (6)	Sec. 18, T 04 N, R 11 W	6,020'	01/11/61	01/18/61	GSI
Union, Kenai No. KU 44-30 (19)	Sec. 30, T 05 N, R 11 W	------	09/12/68	09/19/68	PGW
Socal, Falls Creek No. 1	Sec. 06, T 01 N, R 12 W	13,795'	12/07/60	04/04/61	GSI
Socal, North Fork No. NFU 41-35 (1)	Sec. 35, T 04 S, R 14 W	12,812'	08/09/65	10/31/65	GSI
Halbouty AK Oil, West Fork No. WF 1-B	Sec. 21, T 06 N, R 09 W	14,019'	06/15/60	09/15/60	AGW
Chevron USA, Swanson River No. SCU 12A-3	Sec. 03, T 07 N, R 09 W	10,851'	02/07/61	03/23/61	OSI
Chevron USA, Swanson River No. SCU 12-4 (12)	Sec. 04, T 07 N, R 09 W	10,974'	02/25/61	04/03/61	POW
Chevron USA, Swanson River No. SCU 12-A-4	Sec. 04, T 07 N, R 09 W	10,880'	05/25/74	06/27/74	POW
Chevron USA, Swanson River No. SCU 12A-10	(BH) Sec. 10, T 07 N, R 09 W	------	11/14/75	01/09/76	POW
Chevron USA, Swanson River No. 12-16 (14)	Sec. 16, T 07 N, R 09 W	12,759'	03/01/61	04/26/61	D&A
Socal, Swanson River No. SCU 13-3	Sec. 03, T 07 N, R 09 W	------	09/23/75	11/16/75	Sus
Socal, Swanson River No 13-4	(BH) Sec. 04, T 07 N, R 09 W	------	04/ /75	06/ /75	POW
Socal, Swanson River No. 13-9	Sec. 09, T 07 N, R 09 W	------	09/12/82	10/14/82	OSI
Socal, Swanson River No. 13-34	(BH) Sec. 34, T 08 N, R 09 W	------	08/21/71	12/13/71	POW
Socal, Swanson River No. 14-3	Sec. 03, T 07 N, R 09 W	10,850'	06/16/61	07/24/61	OSI
Socal, Swanson River No. 14-5	Sec. 05, T 07 N, R 09 W	11,450'	09/08/69	10/23/69	POW
Socal, Swanson River No. 14A-5	Sec. 05, T 07 N, R 09 W	------	11/16/75	12/02/75	POW
Socal, Swanson River No. 14-9	Sec. 09, T 07 N, R 09 W	11,046'	10/28/60	12/11/60	POW

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Socal, Swanson River No. 14A-9	Sec. 09, T 07 N, R 09 W	10,951'	08/27/74	09/16/74	POW
Socal, Swanson River No. 14-34	Sec. 34, T 08 N, R 09 W	10,870'	10/30/60	12/09/60	POW
Socal, Swanson River No. 21-3	Sec. 03, T 07 N, R 09 W	11,100'	11/09/61	12/20/61	OSI
Socal, Swanson River No. 21-4 (25)	Sec. 04, T 07 N, R 09 W	10,896'	07/21/61	09/17/61	POW
Socal, Swanson River No. 21A-4	Sec. 04, T 07 N, R 09 W	10,896'	07/19/61	09/17/61	POW
Socal, Swanson River No. 21-8	Sec. 08, T 07 N, R 09 W	11,000'	12/16/62	02/05/63	POW
Socal, Swanson River No. 21-9	Sec. 09, T 07 N, R 09 W	10,747'	05/18/61	07/05/61	POW
Socal, Swanson River No. 21-16 (37)	Sec. 16, T 07 N, R 09 W	11,055'	05/20/63	06/29/63	AOW
Socal, Swanson River No. 21A-16	Sec. 16, T 07 N, R 09 W	10,910'	08/02/75	08/27/75	POW
Socal, Swanson River No. 21B-16	Sec. 16, T 07 N, R 09 W	------	--------	--------	---
Socal, Swanson River No. 22-32	Sec. 32, T 07 N, R 09 W	14,550'	04/29/62	09/21/62	D&A
No. 22A-32 (34)	Redrill	14,796'	12/22/62	04/13/63	D&A
Socal, Swanson River No. 23A-3	Sec. 03, T 07 N, R 09 W	10,948'	07/12/63	11/12/63	POW
	Redrill	10,948'	06/30/73	07/23/73	POW
Socal, Swanson River No. 24-5	Sec. 05, T 07 N, R 09 W	10,996'	07/29/73	09/26/73	POW
Socal, Swanson River No. 24-9	Sec. 09, T 07 N, R 09 W	------	--------	--------	---
Socal, Swanson River No. 24A-9	Sec. 09, T 07 N, R 09 W	11,030'	05/22/75	09/07/75	POW
Socal, Swanson River No. 24-34	Sec. 34, T 08 N, R 09 W	------	09/02/70	10/07/70	OSI
Socal, Swanson River No. 31-8	Sec. 08, T 07 N, R 09 W	------	06/26/82	08/23/82	POW
Socal, Swanson River No. 31-16	Sec. 16, T 07 N, R 09 W	11,239'	07/05/69	08/17/69	AOW
Socal, Swanson River No. 31A-16	(BH) Sec. 16, T 07 N, R 09 W	11,026'	04/28/75	05/30/75	OSI
Socal, Swanson River No. 32-5(31)	Sec. 05, T 07 N, R 09 W	11,152'	01/09/62	02/28/62	D&A
Socal, Swanson River No. 32A-5	Sec. 05, T 07 N, R 09 W	------	10/17/73	02/01/74	POW
Socal, Swanson River No. 32-8(10)	Sec. 08, T 07 N, R 09 W	10,828'	01/03/61	02/16/61	POW
Socal, Swanson River No. 32-9(9)	Sec. 09, T 07 N, R 09 W	10,830'	12/03/60	01/09/61	POW
Socal, Swanson River No. 32A-9	Sec. 09, T 07 N, R 09 W	------	07/16/74	08/10/74	POW
Socal, Swanson River No. 33-5	Sec. 05, T 07 N, R 09 W	10,870'	08/25/75	10/17/75	POW
Socal, Swanson River No. 33-8	Sec. 08, T 07 N, R 09 W	11,100'	03/13/73	05/12/73	POW

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Socal, Swanson River No. 33-33	Sec. 33, T 08 N, R 09 W	------	07/23/76	12/09/76	OSI
Socal, Swanson River No. SCU 34-4	Sec. 04, T 07 N, R 09 W	10,880'	10/14/60	11/16/60	OSI
Socal, Swanson River No. 34-5	Sec. 05, T 07 N, R 09 W	11,220'	08/09/61	09/30/61	POW
Socal, Swanson River No. 34-8(29)	Sec. 08, T 07 N, R 09 W	11,175'	11/07/61	12/27/61	POW
Socal, Swanson River No. 34-9	Sec. 09, T 07 N, R 09 W	11,038'	09/25/61	10/31/61	POW
Socal, Swanson River No. 34-16	Sec. 16, T 07 N, R 09 W	11,881'	01/09/62	03/17/62	D&A
Socal, Swanson River No. 34-33	Sec. 33, T 08 N, R 09 W	10,815'	09/30/60	11/02/60	POW
Socal, Swanson River No. 41-5	Sec. 04, T 07 N, R 09 W	11,450'	07/23/61	09/05/61	POW
Socal, Swanson River No. 41-9A	Sec. 09, T 07 N, R 09 W	10,852'	05/05/61	06/03/61	POW
Socal, Swanson River No. 42-5	Sec. 05, T 07 N, R 09 W	11,170'	01/08/72	04/20/72	POW
Socal, Swanson River No. 42A-5	Sec. 05, T 07 N, R 09 W	------	01/08/72	04/20/72	POW
Socal, Swanson River No. 42B-5	Sec. 05, T 07 N, R 09 W	------	12/07/83	02/09/83	POW
Socal, Swanson River No. 43-4(16)	Sec. 04, T 07 N, R 09 W	11,048'	03/29/61	05/02/61	D&A
Socal, Swanson River No. 43A-4	Sec. 04, T 07 N, R 09 W	------	03/29/61	05/02/61	---
	Redrill		12/05/74	02/26/76	OSI
Socal, Swanson River No. 43A-4RD	Sec. 04, T 07 N, R 09 W	------	12/05/74	02/26/75	POW
Socal, Swanson River No. 43-5(18)	Sec. 05, T 07 N, R 09 W	10,852'	04/27/61	05/23/61	OSI
Socal, Swanson River No. 43A-5	Sec. 05 T 07 N, R 09 W	10,650'	01/18/73	01/12/73	POW
Socal, Swanson River No. 43B-5	Sec. 05, T 07 N, R 09 W	------	--------	--------	---
Socal, Swanson River No. 43-8	Sec. 08, T 07 N, R 09 W	10,886'	03/12/61	04/19/61	AOW
Socal, Swanson River No. 43A-8	Sec. 08, T 07 N, R 09 W	10,886'	03/16/74	05/08/74	POW
Socal, Swanson River No. 43-9	Sec. 09, T 07 N, R 09 W	11,101'	02/10/63	03/27/63	POW
Socal, Swanson River No. 44-4	(BH) Sec. 04, T 07 N, R 09 W	------	11/11/75	03/30/75	POW
Socal, Swanson River No. 44-8	Sec. 08, T 07 N, R 09 W	11,298'	10/09/75	12/19/74	POW
Socal, Swanson River No. 44A-8	Sec. 08, T 07 N, R 09 W	11,298'	10/14/81	11/01/81	POW
Socal, Swanson River No. 243-4(26)	Sec. 04, T 07 N, R 09 W	------	07/26/61	08/08/61	MDW
Socal, Swanson River No. 243-8(33)	Sec. 08, T 07 N, R 09 W	6,143'	02/03/62	02/15/62	PGW
Socal, Swanson River No. 319-9	Sec. 09, T 07 N, R 09 W	10,785'	08/16/60	09/29/60	GIW

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Socal, Swanson River No. 314-4	Sec. 04, T 07 N, R 09 W	11,520'	06/04/60	08/13/60	GIW
Socal, Swanson River No. 323-4	Sec. 04, T 07 N, R 09 W	10,775'	04/12/61	05/22/61	GIW
Socal, Swanson River No. 323-9	Sec. 09, T 07 N, R 09 W	10,750'	05/30/61	07/08/61	GIW
Socal, Swanson River No. 332-4	Sec. 04, T 07 N, R 09 W	11,119'	03/30/60	05/21/60	GIW
Socal, Swanson River No. 341-4	Sec. 04, T 07 N, R 09 W	11,315'	12/03/59	03/20/60	GIW
Socal, Swanson River No. 341-8	Sec. 08, T 07 N, R 09 W	10,814'	06/05/61	07/05/61	GIW
Socal, Swanson River No. 343-33	Sec. 33, T 08 N, R 09 W	10,995'	12/30/60	03/01/61	GIW
Socal, Swanson River No. 412-10(41)	(BH) Sec. 10, T 07 N, R 09 W	11,540'	04/17/72	05/20/72	WIW
Socal, Swanson River No. SRU 12-15(12)	Sec. 15, T 08 N, R 09 W	11,383'	07/24/60	09/15/60	POW
Socal, Swanson River No. 12-27(6)	Sec. 27, T 08 N, R 09 W	11,500'	07/04/59	11/06/59	POW
Socal, Swanson River No. 12-34(13)	Sec. 34, T 08 N, R 09 W	11,032'	09/04/60	10/08/60	POW
Socal, Swanson River No. 14-9(33)	Sec. 09, T 08 N, R 09 W	14,360'	09/29/62	04/13/63	D&A
Socal, Swanson River No. 14-15(4A)	Sec. 15, T 08 N, R 09 W	11,460'	03/29/59	06/09/55	OSI
Socal, Swanson River No. 14-22(3A)	Sec. 22, T 08 N, R 09 W	11,000'	12/14/62	01/22/63	POW
Socal, Swanson River No. 14A-33(29)	Sec. 33, T 08 N, R 09 W	11,125'	04/16/62	06/02/62	POW
Socal, Swanson River No. 21-15(19)	Sec. 15, T 08 N, R 09 W	11,344'	04/09/61	06/01/61	OSI
Socal, Swanson River No. 21-22(26)	Sec. 22, T 08 N, R 09 W	11,012'	11/14/61	12/21/61	POW
Socal, Swanson River No. 21-27(18)	Sec. 27, T 08 N, R 09 W	11,142'	03/18/61	04/24/61	POW
Socal, Swanson River No. 21-34(35)	Sec. 34, T 08 N, R 09 W	11,065'	02/07/63	03/15/63	POW
Socal, Swanson River No. 22-23(3)	Sec. 23, T 08 N, R 09 W	11,653'	08/21/58	10/25/58	WIW
Socal, Swanson River No. 23-15(17)	Sec. 15, T 08 N, R 09 W	11,240'	02/13/61	03/29/61	POW
Socal, Swanson River No. 23-22(9)	Sec. 22, T 08 N, R 09 W	11,614'	01/04/60	02/24/60	POW
Socal, Swanson River No. 23-27	Sec. 27, T 08 N, R 09 W	11,384'	11/24/60	01/27/61	POW
Socal, Swanson River No. 23-33(20)	Sec. 33, T 08 N, R 09 W	10,895'	05/08/61	06/02/61	POW
Socal, Swanson River No. 24-33	Sec. 33, T 08 N, R 09 W	11,088'	09/25/72	11/30/72	POW
Socal, Swanson River No. 31-15	Sec. 15, T 08 N, R 09 W	11,890'	04/18/77	07/01/77	POW
Socal, Swanson River No. 31-27(2)	Sec. 27, T 08 N, R 09 W	12,046'	11/10/57	02/15/58	POW

APPENDIX B (cont.)
Kenai Peninsula Well Information Summary

Well Name	Location*	TD	Drilled	Completed	Status**
Socal, Swanson River No. 31-33	Sec. 33, T 08 N, R 09 W	2,461'	05/20/81	05/24/81	WDW
Socal, Swanson River No. 32-22(7)	Sec. 22, T 08 N, R 09 W	11,773'	11/03/59	12/31/59	D&A
Socal, Swanson River No. 32-27(14)	Sec. 27, T 08 N, R 09 W	11,604'	10/10/60	11/21/60	D&A
Socal, Swanson River No. 32-33(11)	Sec. 33, T 08 N, R 09 W	11,385'	06/21/60	08/04/60	OSI
Socal, Swanson River No. 32-33WD	Sec. 33, T 08 N, R 09 W	2,499'	05/25/81	05/28/81	WDW
Socal, Swanson River No. 34-10	Sec. 10, T 08 N, R 09 W	12,384'	04/05/57	08/24/57	POW
Socal, Swanson River No. 34-16(4)	Sec. 16, T 08 N, R 09 W	12,582'	01/04/59	03/23/59	D&A
Socal, Swanson River No. 34-28(36)	Sec. 28, T 08 N, R 09 W	10,880'	03/30/63	05/06/63	POW
Socal, Swanson River No. 41A-15(32)	Sec. 15, T 08 N, R 09 W	11,420'	10/05/62	12/09/62	POW
Socal, Swanson River No. 41-28(25)	Sec. 28, T 08 N, R 09 W	11,211'	10/16/61	11/28/61	D&A
Socal, Swanson River No. 41-33(12A)	Sec. 33, T 08 N, R 09 W	3,000'	08/08/60	08/11/60	WDW
Socal, Swanson River No. 41-33(15)	Sec. 33, T 08 N, R 09 W	11,133'	01/22/61	03/06/61	OSI
Socal, Swanson River No. 43-15(23)RD	Sec. 15, T 08 N, R 09 W	11,380'	07/16/61	10/09/61	OSI
Socal, Swanson River No. 43-28(21)	Sec. 28, T 08 N, R 09 W	10,875'	06/16/61	07/15/61	POW
Socal, Swanson River No. 44-33	(BH) Sec. 33, T 08 N, R 09 W	------	--------	--------	---
Socal, Swanson River No. 211-15(27)	Sec. 15, T 08 N, R 09 W	5,709'	03/17/62	03/26/62	OGSI
Socal, Swanson River No. 212-10(10)	Sec. 10, T 08 N, R 09 W	12,029'	03/17/60	05/14/60	OSI
Socal, Swanson River No. 212-27(24)	Sec. 27, T 08 N, R 09 W	7,800'	08/21/61	09/29/61	OSI
Socal, Swanson River No. 221-33(30)	Sec. 33, T 08 N, R 09 W	3,805'	04/22/62	04/26/62	WDW
Socal, Swanson River No. 222-21(28)	Sec. 21, T 08 N, R 09 W	9,001'	03/20/62	04/19/62	D&A
Socal, Swanson River No. 314-27(8)	Sec. 27, T 08 N, R 09 W	11,436'	12/26/59	06/03/60	GSI
Socal, Swanson River No. 331-27(2)	Sec. 27, T 08 N, R 09 W	12,046'	11/10/57	02/15/58	GSI
Socal, Swanson River No. 421-22(31)	Sec. 22, T 08 N, R 09 W	11,000'	06/15/62	07/30/62	GSI
Socal, Swanson River No. 432-15(5)	Sec. 15, T 08 N, R 09 W	11,982'	08/05/59	10/03/59	GSI
Socal, Swanson River No. 434-15(22)	Sec. 15, T 08 N, R 09 W	11,190'	06/21/61	07/29/61	GSI

* Seward Meridian, (BH) means the given location is a "bottom hole" location.

** D&A - "Dry" and abandoned well, may not be dry but only subeconomic; SUS - suspended well; PGW - producing gas well; POW - producing oil well; GSI - shut in gas well; OSI - shut in oil well; OGSI - shut in oil and gas well; AOW - abandoned oil well; MDW - mud disposal well; WDW - water disposal well; GIW - gas injection well; WIW - water injection well; AGW - abandoned gas well.

APPENDIX C
BLM's Mineral Potential Classification System
(from BLM Manual, Chapter 3131)

Mineral Potential Classification System

I. Level of Potential

O. The geologic environment, the inferred geologic processes, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.

L. The geologic environment and the inferred geologic processes indicate low potential for accumulation of mineral resources.

M. The geologic environment, the inferred geologic processes, and the reported mineral occurrences or valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources.

H. The geologic environment, the inferred geologic processes, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The "known mines and deposits" do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

ND. Mineral(s) potential not determined due to lack of useful data. This notation does not require a level-of-certainty qualifier.

II. Level of Certainty

A. The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

For the determination of No Potential, use O/D. This class shall be seldom used, and when used it should be for a specific commodity only. For example, if the available data show that the surface and subsurface types of rock in the respective area is batholithic (igneous intrusive), one can conclude, with reasonable certainty, that the area does not have potential for coal.

*As used in this classification, potential refers to potential for the presence (occurrence) of a concentration of one or more energy and/or mineral resources. It does not refer to or imply potential for development and/or extraction of the mineral resource(s). It does not imply that the potential concentration is or may be economic, that is, could be extracted profitably.

APPENDIX D

OIL AND GAS DEMAND AND SUPPLY RELATIONSHIPS

The importance of potential oil and gas resources from this refuge is dependent on the hydrocarbon potential of the area, national need for additional sources of oil and gas, and the economics of exploring and producing any hydrocarbons that might be discovered. This Appendix provides a detailed review of the factors that have contributed to the present domestic oil and gas situation and possible future demand for oil and gas, which is directly linked to the national need for oil and gas resources from the refuge.

Domestic Energy Trends

The domestic energy situation, as it relates to oil and gas consumption and production, has changed dramatically since the early 1970s. In 1970, petroleum and natural gas supplied 44 and 33 percent (United States Department of Energy, Energy Information Administration, 1984), respectively, of the total energy consumed in the United States (figure 1A). By 1977, petroleum accounted for nearly 49 percent of domestic energy consumption, and natural gas declined through 1985 when petroleum supplied nearly 42 percent and natural gas contributed approximately 25 percent of total energy demand. Figure 1 graphically depicts the contribution of each major primary energy source to total national energy demand in 1970, 1980, and 1985. Coal, nuclear, and geothermal energy were the primary forms of energy to increase their market share of total energy consumption during this time period at the expense of petroleum and natural gas resources.

Total domestic energy consumption peaked at 78.9 Quadrillion (QUAD) British thermal units (BTU) in 1979 and subsequently declined to 73.8 QUADS in 1985 (United States Department of Energy, Energy Information Administration, 1986). Over the 15-year period from 1970 to 1985, total primary energy consumption increased 11 percent from 66.4 QUADS to 73.8 QUADS; however, the rapid increase in energy consumption and escalation in the cost of energy (the cost of energy more than doubled from 1.35 constant 1972 dollar per million BTU in 1970 to 2.90 in 1981) during this time period resulted in a dramatic change in national energy consumption patterns. Total energy consumed per constant 1972 dollar of Gross National Product (GNP) ranged from 56,500 to 61,000 BTUs per 1972 dollar of GNP for 1960 through 1976 (United States Department of Energy, Energy Information Administration, 1985a). A decline in the intensity of energy utilization was realized in 1977, when total energy consumption dropped to 55,700 BTUs per 1972 dollar of GNP, and this downward trend continued through 1985, when energy consumption was reduced to 42,900 BTUs per 1972 dollar of GNP (United States Department of Energy, Energy Information Administration, 1986). The decline in energy consumption was led by the reduction in the intensity of petroleum and natural gas utilization. In 1985, only 68 percent as much petroleum and natural gas were consumed per

FIGURE 1

PRIMARY ENERGY CONSUMPTION BY SOURCE

FIGURE 1A
1970
Total = 66.4 Quadrillion Btu

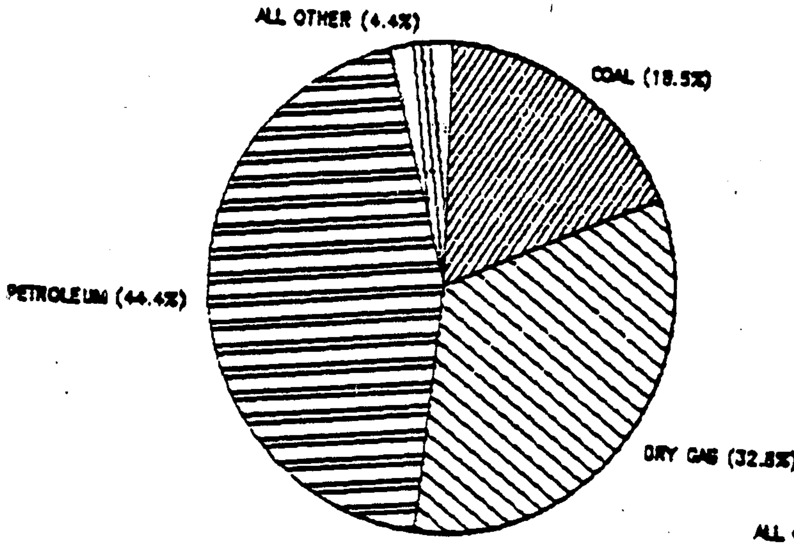


FIGURE 1B
1980
Total = 78.0 Quadrillion Btu

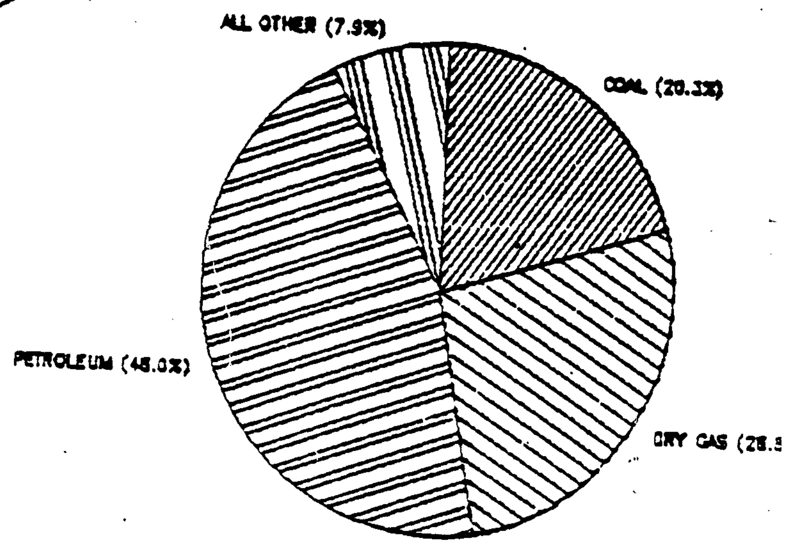
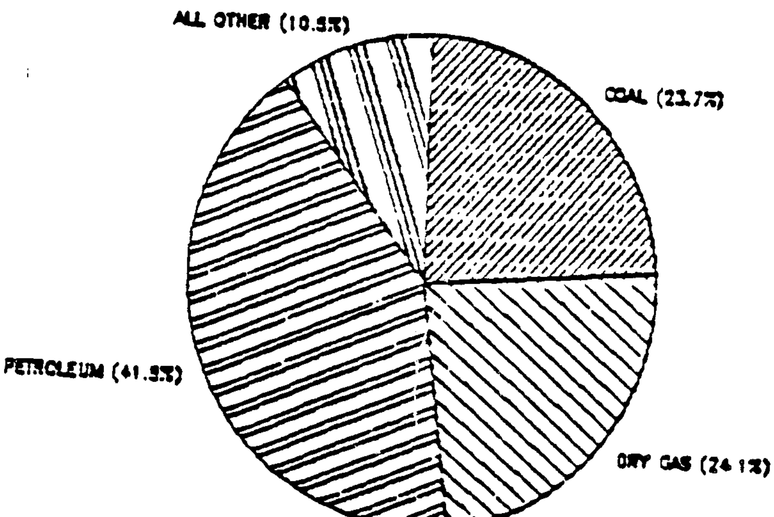


FIGURE 1C
1985
Total = 73.8 Quadrillion Btu



dollar of GNP than in 1977, as compared to 77 percent for total energy consumption. The reduction in intensity of energy utilization was indicative of a national conservation effort which may be attributed to many factors including: increased real energy prices, the increased service orientation of the economy, and changes in the mix of product production (United States Department of Energy, Energy Information Administration, 1985a).

Historical Oil and Gas Demand, Supply, and Price Relationships

The relationship between price and domestic petroleum supply and demand is shown in figures 2 and 3. Import prices utilized for petroleum in figure 3 are represented by the national average refiner's acquisition cost of imported crude oil and wellhead prices are presented on the basis of the national average for all producing wells. Domestic crude oil prices were not completely decontrolled until January 1981; therefore, domestic wellhead prices do not follow import prices during the 1970s. Petroleum product demand rose throughout the early 1970s, until it peaked at 18.8 million barrels per day (MBPD) in 1978 (United States Department of Energy, Energy Information Administration, 1986a). Crude oil price increases began with the Arab oil embargo in 1973, and a second major price run-up was triggered in 1978 by the Iranian revolution and subsequent oil stock building in anticipation of world oil shortages. Real import prices peaked at $44.00 per barrel (1985 dollars) in 1980.

Domestic petroleum product demand began a downward slide in 1979, which continued through 1983. The Organization of Petroleum Exporting Countries (OPEC) members sought to maintain the higher prices, that resulted from oil price shocks of the 1970s, by production restraints. However, oil prices have steadily declined since 1981 as a result of slow economic growth with subsequent declining petroleum demand and excess world productive capacity (United States Department of Energy, Energy Information Administration, 1986b). Domestic oil prices in the second quarter of 1986 had declined to the lower teens in nominal terms which is comparable to 1973 prices in real dollars. Figures 2 and 3 show that petroleum demand is sensitive to price and is characterized by long lags and high elasticities.

Domestic petroleum production has been much more stable than petroleum product demand. Figure 2 shows that Alaskan production, primarily from the North Slope, contributes a significant portion of domestic supply. In 1985, Alaska accounted for more than 20 percent of the national crude oil production (United States Department of Energy, Energy Information Administration, 1986a). Price increases of the 1970s provided incentive for exploration and production from higher cost areas such as Alaska. Foreign imports have been required to fill the gap between domestic supply and demand. Crude oil and petroleum product imports peaked in 1977, when net imports accounted for more than 46 percent of domestic petroleum consumption. Net petroleum import levels declined to 27 percent of product demand in 1985, but the United States still remains highly dependent on foreign petroleum supply sources.

FIGURE 2
NATIONAL PETROLEUM DEMAND

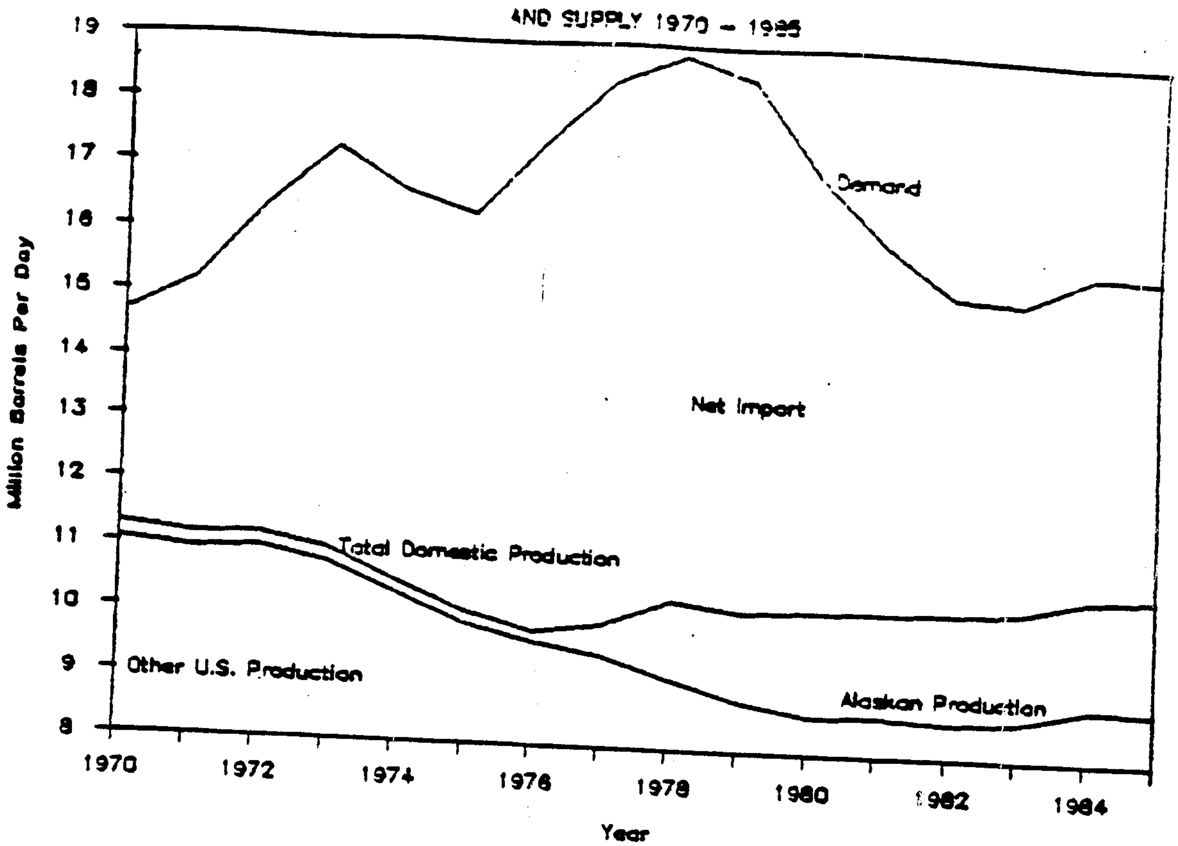
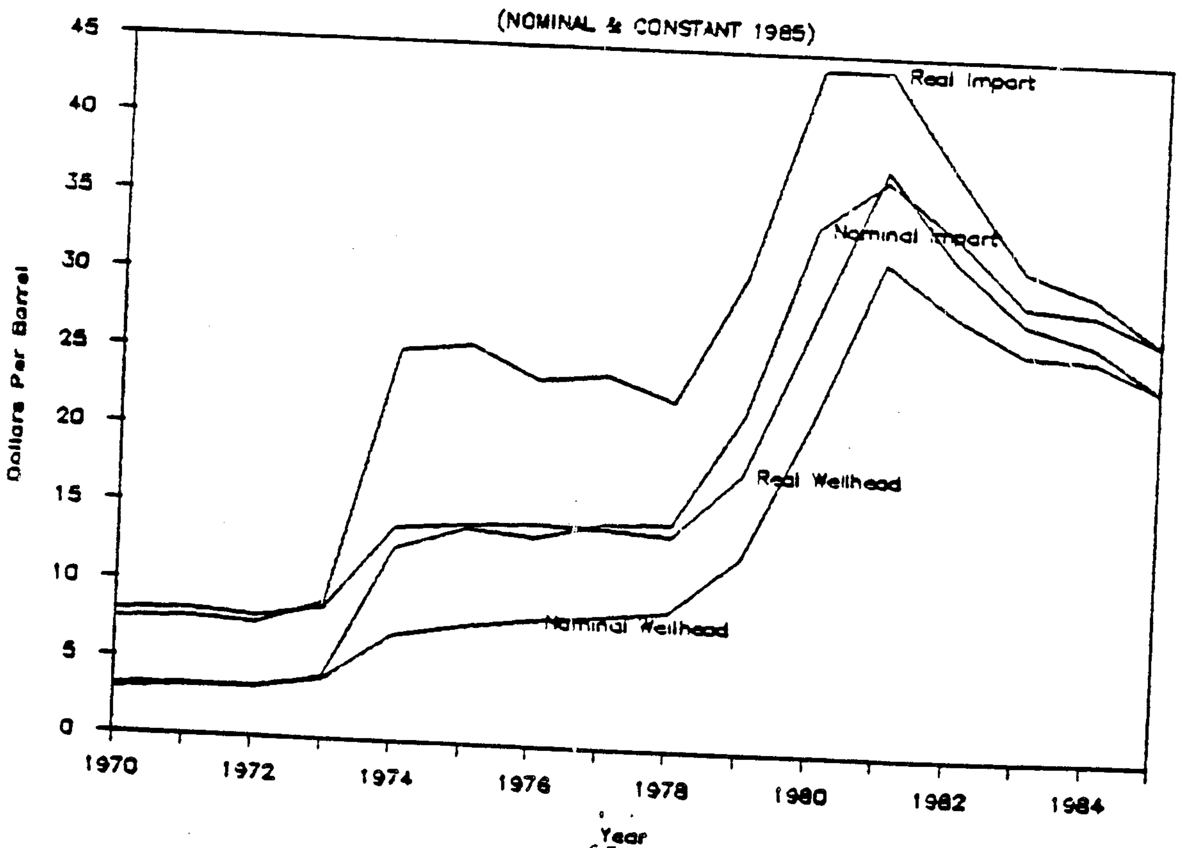


FIGURE 3
CRUDE OIL PRICES



The history of natural gas production and consumption in the United States is quite different from petroleum, and it has a direct bearing on gas pricing policies, demand and supply relationships in the 1970s and 1980s (figures 4 and 5). Natural gas went from a little-used waste by-product of oil production in the 1930s to a source of energy that supplied nearly 33 percent of national consumption in 1970 (figure 1A). By 1970, gas was being delivered to consumers at prices well below those of competing petroleum products (United States Department of Energy, Energy Information Administration, 1984) Prices paid to gas producers by interstate pipeline companies were held at low levels through regulation by the Federal Power Commission, which resulted in increased demand and reduced incentives for producers to explore and develop new gas reserves. Regulated prices allowed intrastate transmission companies and distributors to bid natural gas supplies away from interstate carriers (Trussing and Barlow, 1984). The 1970s has been noted for the gas supply shortages in the midwest and northern states. Imported gas prices increased in a pattern similar to oil prices, but domestic prices remained under regulation. The Natural Gas Policy Act was passed in 1978, which allowed wellhead prices to increase and deregulated certain categories of gas. Price increases provided incentives to explore and develop new sources of gas. Natural gas consumption started a sharp decline after 1980 under the influence of higher gas prices, a weak economy, warm winters, and, since 1981, falling oil prices (United States Department of Energy, Energy Information Administration, 1984). This trend continued through 1985, with the exception of a small increase in gas demand realized in 1981 which may be attributed to the strong economic growth in the national economy in that year.

Net imports of natural gas are primarily received through pipelines from Canada and Mexico, although there are some liquified natural gas (LNG) imports from Algeria. Net imports generally ranged near five percent from 1970 to 1985. Alaska is a relatively small producer of natural gas, ranging from approximately 100 to 325 billion cubic feet per year from 1970 to 1985 (United States Department of Energy, Energy Information Administration, 1985b).

Alaska is, however, a net exporter of natural gas in the form of LNG, which is delivered to Japan. Huge gas reserves have been identified on the Alaskan North Slope, but this resource has not been commercially produced due to a lack of transportation infrastructure.

Future Oil and Gas Demand, Supply, and Price Relationships

From the review of historic petroleum and natural gas price, demand, and supply relationships, it is apparent that there have been fundamental changes, such as petroleum price deregulation and energy conservation efforts, in the national energy market since the early 1970s that will likely affect future petroleum and natural gas production and consumption. At the present time, the national petroleum market is directly linked to the world petroleum market by price and supply. The situation is characterized by excess productive capacity in the world market, a strong desire by exporting nations to sell

FIGURE 4
NATIONAL NATURAL GAS DEMAND

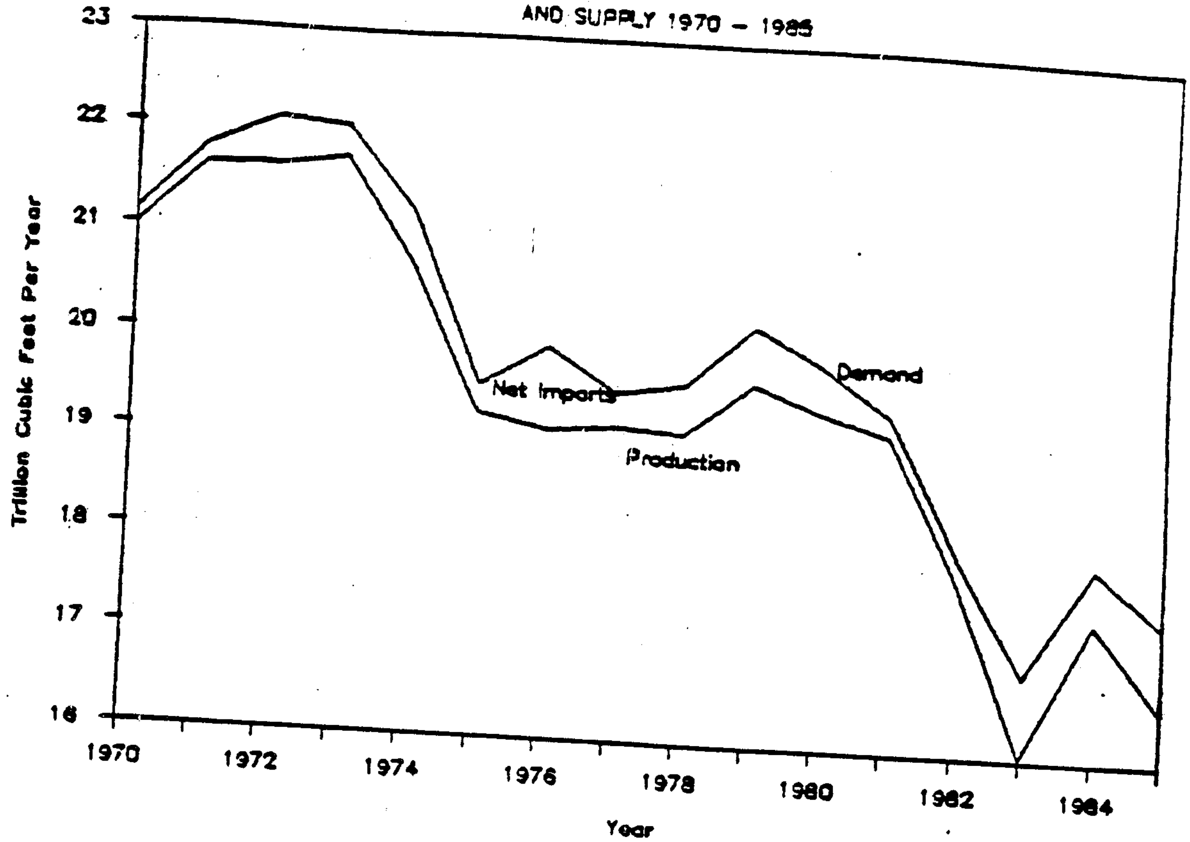
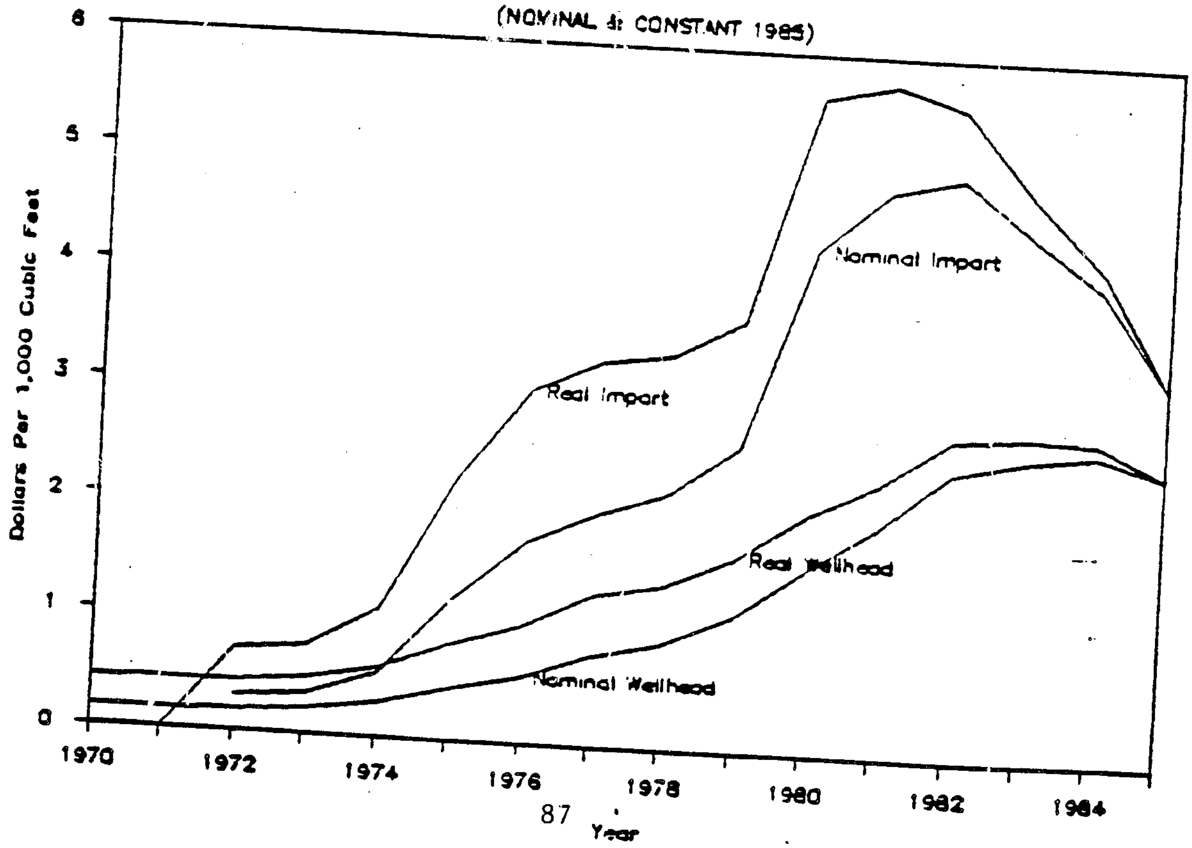


FIGURE 5
NATURAL GAS PRICES



petroleum to meet financial obligations, a time of relatively slow economic growth, and declining petroleum prices. The domestic natural gas industry is currently working off surplus reserves added during the early 1980s, but depressed prices have resulted in a sharp reduction in drilling which could have serious implications for future domestic gas production.

Implications of the petroleum price slide during the first half of 1986 are not yet fully discernable. Middle eastern nations have been unable to reach accord in setting and adherence to self-imposed oil production quotas. In the past, Saudi Arabia has taken the position as swing producer for OPEC and thereby reduced production to maintain quota levels. However, Saudi Arabia changed policies in 1986 to concentrate on achieving a "fair market share" of the international petroleum market with little concern for output quotas. The strategy behind this policy was not disclosed, but speculation as to the potential motivation and results of this action includes:

1. Saudi Arabia is making a show of strength to discipline OPEC members that have cheated on production quotas and prices with hopes of bringing member and possibly non-member nations together as a unified market group;

2. Saudi Arabia sought to increase revenue, but underestimated the effects additional production would have on price;

3. Saudi Arabia is flooding the world oil market in an effort to eliminate producers with higher costs of production and thereby reduce competition;

4. Saudi Arabia is acting to reduce prices and stimulate growth in petroleum demand to reverse conservation efforts initiated in the late 1970s and 1980s.

In any event, a tremendous amount of uncertainty exists in the national petroleum industry, which has resulted in major financial restructuring. The most evident signs of restructuring are major employment reductions and reduced capital expenditures for exploration and drilling.

The interest in mineral exploration and possible development in this refuge is driven by the future national demand for oil and gas, the cost and availability of domestic supplies and the hydrocarbon potential of the area. The rate of future economic growth and hydrocarbon prices will be the major determinants of petroleum and natural gas demand. Future domestic production is dependent on resource availability and market prices. However, political forces are having an increasingly important affect on world oil prices, which will ultimately dictate future market conditions. The instability in the world oil market results in tremendous uncertainty in predicting future hydrocarbon prices and market conditions. Table 1 presents three recent crude oil and natural gas price forecasts by the United States Department of Energy, a private research firm, and a major oil company. The prices shown in these forecasts are significantly lower than previous forecasts completed earlier in

TABLE 1

PETROLEUM AND NATURAL GAS PRICE FORECASTS1/

($/MCF)	Crude Oil ($/Barrel)			Natural Gas		
Reference	1990	2000	2010	1990	2000	2010
U.S. Department of Energy, 19852/						
Low Economic Growth	20.27	31.31	47.42	2.54	4.13	6.02
Reference Case	22.89	36.75	56.77	2.76	4.80	7.68
High Economic Growth	25.02	42.17	67.12	2.88	5.42	9.14
Data Resources Incorporated, 19862/	16.91	34.32	49.99	1.69	3.80	5.76
Chevron Corporation, 19863/						
Low Case	12.00	18.00	N/A	Rise to parity with fuel oil prices.		
High Case	27.50	35.00	N/A			

1/ Some of the price estimates presented in this table were interpreted from graphic displays and/or extrapolated from data series, so the reported prices may vary slightly from the actual values.

2/ Reported on the basis of constant 1984 dollars.

3/ Reported on the basis of constant 1985 dollars.

the 1980s. The range of oil prices projected in these forecasts is $18.00 to $42.00 (constant 1984 and 1985 dollars) per barrel in the year 2000. The high price range is approximately equivalent to the average annual refiner's acquisition cost of imported crude received in 1981 and 1982 (constant 1984 dollars). The range of prices projected for the year 2010 is $47.00 to $67.00 per barrel. These prices would be substantially above the peak levels paid in the early 1980s. Natural gas prices are projected to range between $4.10 and $5.50 per thousand cubic feet (MCF) in the year 2000, and $6.00 to $9.10 per MCF in the year 2010. The magnitude of projected natural gas price increases is similar to forecast changes in world oil prices.

Projections of future domestic petroleum and natural gas demand and supply conditions is presented in table 2. All three forecasts projected an upward trend in petroleum demand above current levels. Petroleum consumption is projected to range form 15.9 to 18.1 MBPD in the year 2000, and possibly increase to 19.4 MBPD by the year 2010. In comparison, domestic petroleum production is projected to decline to levels ranging from 6.1 to 8.9 MBPD by the year 2010. Domestic natural gas demand is projected to increase to a level ranging from 17.1 to 20.4 TCF per year by the year 2000 and then decline to a level of 16.7 to 18.3 TCF per year by 2010. Domestic gas production is projected to follow a similar trend, with domestic oil production and decline to levels ranging from 13.9 to 15.0 TCF per year by the year 2010.

Conclusion

National hydrocarbon markets have undergone substantial changes since the early 1970s. Energy conservation trends initiated by real price increases of the 1970s are expected to continue through the end of this decade and possibly beyond. However, future economic growth is expected to result in some increased demand for petroleum and natural gas, which domestic production of these finite resources is projected to decline. As a result, the United States will become increasingly dependent on foreign hydrocarbon sources to meet national requirements. New areas will need to be explored, and any economically viable resources that are discovered will need to be brought into production in order to meet domestic needs. The potential contribution of this refuge to national oil and gas production is dependent on its resource potential and the potential cost at which any discovered hydrocarbon resources could be extracted and marketed within the constraints of future oil and gas prices.

TABLE 2

FUTURE DOMESTIC PETROLEUM AND NATURAL GAS
DEMAND AND SUPPLY RELATIONSHIPS[1]
(See Table 1 for Price Forecasts)

Reference	Demand			Supply		
	1990	2000	2010	1990	2000	2010
	Petroleum (Millions of Barrels per Day)					
U.S. Department of Energy, 1985						
Low Economic Growth	16.1	15.9	15.5	9.8	9.0	7.8
Reference Case	16.7	16.6	16.5	10.0	9.4	8.3
High Economic Growth	16.8	17.0	17.3	10.0	9.7	8.9
Data Resources Inc., 1986	16.9	18.1	19.4	9.5	7.3	6.1
Chevron Corporation, 1986	16.0	16.8	N/A	9.2	7.0	N/A
	Natural Gas (Trillion Cubic Feet Per Year)					
U.S. Department of Energy, 1985						
Low Economic Growth	18.6	18.8	17.2	17.4	16.1	14.7
Reference Case	19.1	19.7	17.4	17.6	16.3	15.0
High Economic Growth	19.5	20.4	18.3	17.9	16.6	14.7
Data Resources Inc., 1986	18.9	18.1	16.7	16.7	15.3	13.9
Chevron Corporation, 1986	17.3	17.1	N/A	N/A	N/A	N/A

1/ Some of the numeric estimates presented in the table were interpreted from graphic displays and/or extrapolated from data series, so the reported prices may vary slightly from the actual values.